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Effects of Transcutaneous Xenon Light Irradiation around the Stellate Ganglion on Autonomic Functions

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Abstract. [Purpose] The purpose of the present study was to investigate the effects of transcutaneous xenon light irradiation around the stellate ganglion on autonomic functions. [Subjects] Thirty healthy volunteers were the subjects. [Methods] The subjects underwent two experimental sessions: 1) 10-minute xenon light irradiation to the bilateral stellate ganglions in a comfortable supine position (Xe-LISG); and 2) 10-minute rest in the same position as Xe-LISG (control). The low frequency (0.04–0.15 Hz) power (LF) and ratio of LF to the high frequency (0.15–0.40 Hz) power (LF/HF) obtained from power spectral analysis of R-R intervals and skin temperatures of the upper and lower extremities (UE and LE) were examined. [Results] Although no significant changes of HF and LF/HF were observed before and after the control, HF after Xe-LISG was significantly increased compared with that before Xe-LISG, and LF/HF after Xe-LISG was significantly decreased compared with that before Xe-LISG. Additionally, although the UE skin temperature during Xe-LISG tended to be higher than that during the control, the LE skin temperature during Xe-LISG tended to be lower than that during the control. [Conclusion] These results suggest that Xe-LISG inhibits sympathetic activity and induces not only an increase in the UE skin blood flow, but also a decrease in the LE skin blood flow.
Key words: Xenon light, Stellate ganglion, Autonomic functions

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INTRODUCTION

Stellate ganglion block (SGB) is one of the treatment methods for sympathetically maintained pain syndromes and peripheral circulatory disturbances in the upper body (e.g. the upper extremity (UE) and head)[1, 2]. In SGB, the function of the stellate ganglion (SG), which is a sympathetic ganglion sending postganglionic sympathetic fibers to the upper body, is inhibited by injecting anesthetic into the SG region[1, 2], to improve the above-mentioned clinical conditions. Although SGB is an effective treatment method for the above-mentioned clinical conditions, it sometimes causes serious side effects such as shock, respiratory arrest and death[3].

Recently, transcutaneous light irradiation around the SG (LISG) has been utilized instead of SGB. In general, light including the near-infrared spectrum that shows high living body permeability[4] (e.g. low reactive level laser and linear polarized near-infrared light) is used for LISG, and several studies[5, 6] have reported that LISG provided therapeutic effects similar to SGB without side

effects. However, the effectiveness of light therapy using a low reactive level laser and linear polarized near-infrared light is still controversial due to the relatively low output power of both sources[7–9]. Recently, light therapy using xenon light (Xe-light) has received attention[9]. Xe-light is the excitation energy produced by high-voltage discharge to Xe gas, and abundantly includes the near-infrared spectrum. Moreover, the output power of Xe-light produced by a Xe-light treatment device is generally higher than that of a low reactive level laser or linear polarized near-infrared light[9]. In spite of these merits of Xe-light, however, the effects of LISG using Xe-light (Xe-LISG) on autonomic functions have not been sufficiently investigated.

The purpose of the present study was to investigate effects of Xe-LISG on autonomic functions.

SUBJECTS AND METHODS

Subjects

Thirty healthy volunteers (female: 15, male: 15, 23.4 ± 3.6 years old) participated in this study. Written informed consent was obtained from all of them. This study was approved by the committee of medical ethics of Hirosaki University Graduate School of Medicine.

Methods

Each subject underwent two different experimental sessions: Xe-light and control sessions. In both sessions, the subjects engaged in a preliminary 15-minute rest period for stabilization of autonomic activity (stabilization period). During the stabilization period in each session, the subjects were placed in a comfortable supine position, and were instructed to keep awake. In the Xe-light session, after the stabilization period, two probes of a Xe-light treatment device (Excel-Xe, Nihon Iko, Tokyo, Japan) were firmly placed against the skin around the bilateral SGs of the subjects who remained in the supine position of the stabilization period, and thereafter 10 minutes of Xe-light irradiation around the bilateral SGs was performed (Xe-light period). According to the treatment device setting, Xe-light was irradiated at 1-second intervals for 1 minute after the start of the Xe-light period, and at 3.5-second intervals for the remaining 9 minutes of the Xe-light period. The output power and duration of Xe-light per one irradiation were 18000 mW and 5 msec, respectively, and the wavelength ranged between 400 to 1100 nm. In the control session, after the stabilization period, the subjects spent an additional 10-minute period in the supine position of the stabilization period (control period). All experiments were carried out in a temperature-controlled room (approximately 25 degrees C). Each subject underwent the two experimental sessions in the same time zone of two different days. The order of the two sessions was determined at random for each subject. The subjects were instructed to avoid medications and other exposures (i.e. alcohol and caffeinated beverages) that might interfere with autonomic functions during the 12 hours preceding the session.

R-R intervals of the heart rate and skin temperatures of the UE and lower extremity (LE), which reflect the hemodynamics of the UE and LE skins[10], were assessed as indicators of autonomic functions. The R-R intervals were measured through each session using a heart rate monitor (RS800, Polar Electro, Kempele, Finland). The UE and LE skin temperatures were measured at the palmar and plantar sides of the distal interphalangeal (DIP) joint of the bilateral third fingers and third toes using a radiation thermometer (Fluke-572, Fluke Corporation, Everett, USA). In the stabilization period of each session, the UE and LE skin temperatures were measured at the end of the stabilization period, and these data were used as a baseline value. In the Xe-light and control periods, the UE and LE skin temperatures were measured at 1-minute intervals after the start of each period.

For the analysis of the R-R intervals, power spectral analysis software (Polar ProTrainer 5, Polar Electro, Kempele, Finland) was used for the R-R interval data measured in the two minutes before the end of the stabilization period of each session and those measured in the two minutes before the end of the Xe-light and control periods. The low frequency power (LF) from 0.04 to 0.15 Hz, the high frequency power (HF) from 0.15 to 0.40 Hz and the ratio of LF to HF (LF/HF) were calculated. HF and LF/HF are indicators of autonomic activity, and their details are described elsewhere[11, 12].

For the analysis of the UE and LE skin temperatures, all UE and LE skin temperature data measured at 1-minute intervals in the Xe-light and control periods were expressed as a variation from

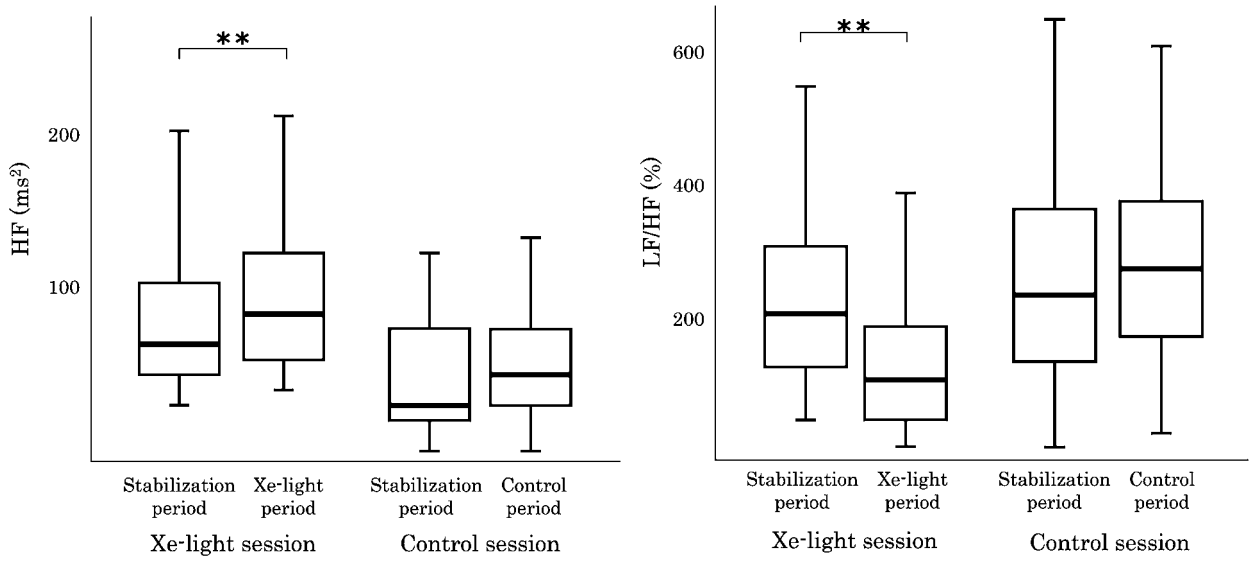

Fig. 1. Changes of HF and LF/HF in the Xe-light and control sessions. **p<0.01.

the corresponding baseline value (i.e. a relative skin temperature). Thereafter, in each period, combining the bilateral UE and LE relative skin temperatures measured at 1-minute intervals, we calculated overall mean values of the UE and LE relative skin temperatures at 1-minute intervals. The overall mean values of the UE and LE relative skin temperatures at 1-minute intervals in the Xe-light and control periods were used for statistical analysis.

For the statistical analysis, HF and LF/HF in the Xe-light and control periods were compared with those in the stabilization periods of the corresponding sessions using Wilcoxon's signed rank test. The overall mean values of the UE and LE relative skin temperatures at 1-minute intervals in the Xe-light and control periods were compared with the baseline (i.e. zero) using Dunnett's multiple comparison test. The overall mean values of the UE and LE relative skin temperatures at 1-minute intervals in the Xe-light period were compared with those in the control period using the paired t test. Before performing the above-mentioned paired t test, we confirmed that there were no significant differences between the actual baseline values of the UE and LE skin temperatures in the Xe-light session and those in the control session using Wilcoxon's signed rank test. All analyses were performed using SPSS 15.0J for Windows, and two-tailed p values<0.05 were considered statistically significant.

RESULTS

No side effects caused by Xe-LISG were noted during the present study.

Figure 1 presents the changes of HF and LF/HF in the Xe-light and control sessions. In the Xe-light session, HF in the Xe-light period was significantly increased compared with that in the stabilization period. Moreover, LF/HF in the Xe-light period was significantly decreased compared with that in the stabilization period. In the control session, on the other hand, no significant changes were observed between HF and LF/HF in the stabilization period and those in the control period.

Figure 2 presents the time courses of the overall mean values of the UE and LE relative skin temperatures in the Xe-light and control periods. In the Xe-light period, although the overall mean values of the LE relative skin temperatures from 4 to 10 minutes were significantly lower than the baseline, no significant changes were observed between the overall mean values of the UE relative skin temperatures at 1-minute intervals and the baseline. In the control period, the overall mean values of both the UE and LE relative skin temperatures from 8 to 10 minutes were significantly lower than the baseline. The actual baseline values (expressed as the median) of the UE skin temperatures in the Xe-light and control sessions were 33.3 degrees C and 33.9 degrees C, respectively, and those of the LE skin temperatures

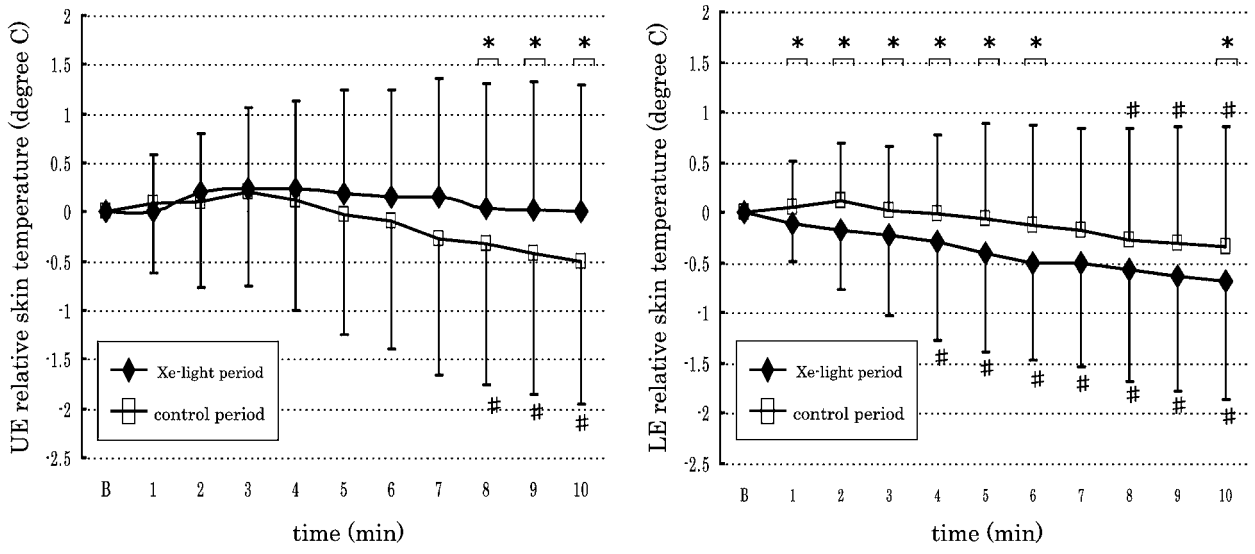

Fig. 2. Time courses of overall mean values of UE and LE relative skin temperatures in the Xe-light and control periods. B, baseline; #, $p<0.05$ versus B; *, $p<0.05$ between the Xe-light and control periods.

in both the sessions were 27.2 degrees C and 26.2 degrees C, respectively. In the statistical analysis, no significant differences were observed between the actual baseline values of the UE and LE skin temperatures in the Xe-light session and those in the control session. Therefore, we judged that it was possible to compare the overall mean values of the UE and LE relative skin temperatures in the Xe-light period with those in the control period. In the comparison between the overall mean values of the UE relative skin temperatures at 1-minute intervals in the Xe-light period and those in the control period, the majority of the former tended to be higher than the latter, and significant differences were observed from 8 to 10 minutes (Fig. 2). In the comparison between the overall mean values of the LE relative skin temperatures at 1-minute intervals in the Xe-light period and those in the control period, on the other hand, the former always tended to be lower than the latter, and significant differences were observed from 1 to 6 minutes and at 10 minutes (Fig. 2).

DISCUSSION

The present study showed that in the Xe-light session, HF in the Xe-light period was significantly increased compared with that in the stabilization period, and LF/HF in the Xe-light period was significantly decreased compared with that in the stabilization period. Additionally, the present study also demonstrated that in the control session, no significant changes of HF and LF/HF were observed between the stabilization and control periods. HF and LF/HF are considered to represent autonomic activity: an increase in HF and a decrease in LF/HF indicate inhibition of sympathetic activity[11, 12]. Therefore, our results suggest that Xe-LISG inhibits sympathetic activity. Several studies[13, 14] have indicated that transcutaneous light irradiation to the peripheral nerve might activate the mechanism of peripheral nerve blockage from the standpoint of sensory nerve activity. Our results support this indication from the standpoint of autonomic activity. From an anatomical viewpoint, nearly all sympathetic innervations of the UE occur via pathways through the SG[2]. Therefore, it is likely that the sympathetic inhibitory effect caused by Xe-LISG spreads to the UE and dilates blood vessels of the UE skin[15].

The present study showed that the UE relative skin temperature in the Xe-light period tended to be higher than that in the control period. We should take into consideration at least two factors as a determinant of skin temperature: the skin blood flow and radiation from the skin[16]. An increase in the skin blood flow would increase skin temperature, and radiation from the skin would decrease it. In both the Xe-light and control periods, the UE skin temperature would have

gradually decreased due to radiation from the UE skin. In the Xe-light period, however, the decrease in the UE skin temperature would be suppressed compared with the control period, because vasodilation in the UE skin due to the sympathetic inhibitory effect caused by Xe-LISG would increase the UE skin blood flow[1, 9]. This is one possible interpretation of the findings of the UE relative skin temperature in this study. On the other hand, the present study demonstrated that the LE relative skin temperature in the Xe-light period tended to be lower than that in the control period. We speculate that the findings of the LE relative skin temperature in this study were also related to the effect of Xe-LISG. In the Xe-light period, if the vasodilation in the UE skin due to the sympathetic inhibitory effect caused by Xe-LISG were to increase the UE skin blood flow, the LE skin blood flow would relatively decrease. If this were the case, then the LE skin temperature in the Xe-light period would be expected to decrease compared with that in the control period, because in the Xe-light period, the LE skin temperature is influenced by both the relative decrease in the LE skin blood flow and radiation from the LE skin. This is a possible interpretation of the findings of the LE relative skin temperature in this study. However, an increase in the LE skin temperature during LISG was reported in a previous study[17], in which linear polarized near-infrared light was used for LISG. This finding may be explained if LISG inhibits the sympathetic activity of the LE and increases the LE skin blood flow. However, there have been few well-designed investigations concerning changes of LE hemodynamics after LISG or SGB. The LE hemodynamics related to LISG and SGB may become an important issue when conducting LISG and SGB for patients with LE peripheral circulatory disturbance. Future studies should focus on the elucidation of the LE hemodynamics after LISG and SGB.

One weakness of this study is that differences between the UE and LE relative skin temperatures in the Xe-light period and those in the control period were small (approximately 0.5 degree C at a maximum, see Fig. 2). In addition, previous studies have not completely clarified the relationship between variation of skin temperature and that of skin blood flow, although skin temperature is an indicator of skin blood flow[10]. Therefore, it may be difficult to appropriately analyze changes of UE and LE hemodynamics after Xe-LISG from the results of this study alone. In order to compensate for the weakness of this study, subsequent studies should measure not only skin temperature but also skin blood flow by using a non-invasive method, such as a doppler flowmeter[18].

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