Does Instability during Standing Occur just after Transcutaneous Xenon Light Irradiation around the Stellate Ganglion?

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Abstract. [Purpose] This study investigated whether instability during standing occurs just after transcutaneous xenon light irradiation around the stellate ganglion. [Subjects] Thirty healthy volunteers were the subjects. [Methods] The subjects underwent two experimental sessions: 1) 10-minute xenon light irradiation around the bilateral stellate ganglions in a comfortable supine position (Xe-LISG); and 2) 10-minute rest in the same position as Xe-LISG (control). After Xe-LISG and the control, they stood up immediately and maintained quiet standing for 1 minute. The low frequency power (LF) and ratio of LF to the high frequency power (LF/HF) based on R-R intervals, and the total length (LNG) and rectangular area (REC) of the excursion of the center of foot pressure during quiet standing 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 greater than that before Xe-LISG, and LF/HF after Xe-LISG was significantly lower than that before Xe-LISG. Additionally, although no significant difference was observed between REC after Xe-LISG and that after the control, LNG after Xe-LISG was significantly longer than that after the control. [Conclusion] These results suggest that Xe-LISG causes not only parasympathetic predominance and sympathetic suppression but also instability during standing just after Xe-LISG.

Key words: Xenon light, Stellate ganglion, Instability during standing

INTRODUCTION

Stellate ganglion block (SGB) is one of the treatment procedures for sympathetically maintained pain syndromes and peripheral circulatory disturbances in the upper body1,2). 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 region1,2). Although SGB is an effective treatment procedure for the above-mentioned clinical conditions, it sometimes causes serious side effects such as shock, respiratory arrest and death, even if it is carried out by skilled physicians3).

Recently, transcutaneous light irradiation around the SG (LISG) has been utilized instead of SGB. Light including the near-infrared spectrum that shows high living body permeability4) (e.g. linear polarized near-infrared light) is used for LISG, and
several studies have reported that LISG provides therapeutic effects similar to SGB without the serious side effects\(^5\),\(^6\). However, the effectiveness of LISG using linear polarized near-infrared light is still controversial due to the relatively low output power\(^7\)–\(^9\). Recently, light therapy using xenon light (Xe-light) has received attention\(^2\),\(^10\). Xe-light is the excitation energy produced by high-voltage discharge to Xe gas, and abundantly includes the near-infrared spectrum. In addition, the output power of Xe-light produced by a Xe-light treatment device is generally higher than that of linear polarized near-infrared light\(^7\),\(^10\). We have reported that LISG using Xe-light (Xe-LISG) induced not only parasympathetic predominance and sympathetic suppression but also hemodynamic changes in the upper and lower extremities in healthy subjects\(^10\). However, the effects of Xe-LISG on exercise performance remain unclear. In clinical situations, Xe-LISG is usually performed on patients who are placed in a comfortable supine position, and they often have to stand up and walk just after Xe-LISG to undergo other medical treatment. Although Xe-LISG does not have serious side effects\(^6\),\(^9\), there is no denying that persons with parasympathetic predominance and sympathetic suppression resulting from Xe-LISG may show instability during standing owing to symptoms with which sympathetic suppression will be closely associated, such as orthostatic hypotension (OH)\(^11\),\(^12\). Hence, from the viewpoint of risk management, whether instability during standing just after Xe-LISG occurs or not should be investigated. However, to our knowledge, there have been no previous studies paying attention to instability during standing just after Xe-LISG.

The purpose of the present study was to investigate whether instability during standing occurs just after Xe-LISG.

**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. Before the start of each session, a heart rate monitor (RS800, Polar Electro, Kempele, Finland), which does not impede human movement, was attached to the subjects, and R-R intervals of the heart rate were measured during each session using the heart rate monitor. 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. 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 (i.e. the skin at a site 2.5 cm above the right and left costoclavicular joints\(^9\)) 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 18 W and 5 msec, respectively, and the wavelength ranged between 400 to 1100 nm. The subjects were instructed to keep awake during the stabilization and Xe-light periods. After the Xe-light period, the subjects stood up on a stabilometer (GS3000, Anima Corp, Tokyo, Japan) immediately, and maintained quiet standing in their bare feet for 1 minute. During the quiet standing, the subjects kept their eyes in a horizontal position by watching a black circle mark 3 meters ahead, and two parameters related to the ability to maintain quiet standing, namely, the total length (LNG) and rectangular area (REC) of the excursion of the center of foot pressure\(^13\), were measured using the stabilometer. The reasons why we adopted the two parameters were as follows: in addition to the high usage rate of these parameters in previous studies, Mizusawa et al. have pointed out that it is possible to evaluate standing balance by REC\(^14\). 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). The subjects were instructed to keep awake.
during the stabilization and control periods. After the control period, the subjects stood up on the stabilometer immediately, and LNG and REC were measured under the same conditions as in the case of the Xe-light session. All experiments were carried out in a temperature-controlled room (approximately 25 degrees C). The two experimental sessions were performed in the same time zone on 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.

For the analysis of the R-R intervals, power spectral analysis software (Polar ProTrainer 5, Polar Electro, Kempele, Finland) was used to analyze the R-R interval data measured in the 2 minutes before the end of the stabilization period of each session and those measured in the 2 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\textsuperscript{15,16}. For the statistical analysis, HF and LF/HF were expressed as the median: [25 percentile, 75 percentile], and HF and LF/HF in the Xe-light and control periods were compared with those measured after the control period using the paired \textit{t} test. All analyses were performed using SPSS Statistics 17.0 for Windows, and two-tailed \textit{p} values<0.05 were considered statistically significant.

## RESULTS

All subjects completed the study protocol without accidents.

Table 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 greater than that in the stabilization period. Moreover, LF/HF in the Xe-light period was significantly lower than 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.

Table 2 presents the differences between LNG and REC measured after the Xe-light period and those measured after the control period. LNG measured after the Xe-light period was significantly longer than that measured after the control period. On the other hand, no significant difference was observed between REC measured after the Xe-light period and that measured after the control period.

## DISCUSSION

The present study showed that in the Xe-light session, HF in the Xe-light period was significantly greater than that in the stabilization period, and LF/ HF in the Xe-light period was significantly lower than that in the stabilization period. A comparatively big difference in the median of HF between the stabilization period in the Xe-light session and that in the control session was also observed (Table 1). If the difference means a
baseline autonomic difference between the Xe-light and control sessions, it might become a problem for the evaluation of autonomic changes associated with the Xe-light and control periods. However, recent studies have tended to evaluate autonomic changes by paying attention to variations in HF and LF/HF before and after LISG and control sessions, with or without baseline HF and LF/HF differences between the sessions. Therefore, we think that the difference in the median of HF between the stabilization period in the Xe-light session and that in the control session is not a serious problem for the evaluation of autonomic changes associated with the Xe-light and control periods. Previous studies have already clarified that an increase in HF and a decrease in LF/HF shows parasympathetic predominance and sympathetic suppression, respectively. Therefore, the results of the present study strongly indicate that Xe-LISG induces parasympathetic predominance and sympathetic suppression. This indication is supported by our previous Xe-LISG study. However, several LISG studies using not Xe-light, but linear polarized near-infrared light, failed to show an effect on autonomic functions. These findings might imply that Xe-LISG is superior to LISG using linear polarized near-infrared light in terms of effect on autonomic functions, although further investigations will be required to clarify the effects of LISG on autonomic functions.

In the present study, LNG and REC were used as indicators of the ability to maintain quiet standing. In general, LNG and REC of persons who have poor ability to maintain quiet standing are greater than those of persons with better abilities. In the present study, although there was no significant difference between REC measured after the Xe-light period and that measured after the control period, LNG measured after the Xe-light period was significantly longer than that measured after the control period. These findings suggest that instability during standing might occur just after Xe-LISG. To our knowledge, this is the first report that has described instability during standing just after Xe-LISG. Therefore, we have few explanations about why instability during standing occurs just after Xe-LISG. We propose that at least two factors are involved in the occurrence of instability during standing just after Xe-LISG. The first factor is OH, and second is diminished arousal.

With regard to OH in active standing-up, we surmise that this is the most important factor which causes instability during standing just after Xe-LISG. In active standing-up, both the systolic and diastolic blood pressures are rapidly decreased just after active standing-up due to the shift of blood volume from the intrathoracic region to the lower body. Under a normal sympathetic condition, the decreased systolic and diastolic blood pressures just after active standing-up are quickly recovered by constriction of the resistance and capacitance vessels, in which the action of the sympathetic nervous system plays an important role. After Xe-LISG, however, the quick recovery of the decreased systolic and diastolic blood pressures just after active standing-up might be inhibited because Xe-LISG causes sympathetic suppression, as shown in the present and previous studies. The quick recovery of the decreased systolic and diastolic blood pressures just after active standing-up is extremely important to prevent the occurrence of OH. Furthermore, OH is closely related to the ability to maintain standing because dizziness due to decreased cerebral blood flow arising from OH can cause instability during standing. Therefore, after Xe-LISG, instability during standing, owing to OH, may occur. This speculation is partially supported by several Xe-LISG studies which have suggested that peripheral circulation of the upper and lower extremities is improved by vasodilation based on sympathetic suppression resulting from Xe-LISG. In order to prove the occurrence of OH in active standing-up just after Xe-LISG, future studies should examine continuous changes of both the systolic and diastolic blood pressures in active standing-up just after Xe-LISG.

The second conceivable factor affecting the stability of standing is diminished arousal. Shinar et al. have pointed out that autonomic balance is shifted towards parasympathetic predominance a few minutes before sleep onset. In general, many people will feel drowsiness at the time. This finding indicates that parasympathetic predominance is associated with diminished arousal levels. In this study, as already stated, parasympathetic predominance was observed only in the Xe-light period. Hence it is likely that the subjects felt drowsiness in the Xe-light period, even if they tried to keep awake. On the other hand, Lipov et al. have reported that SGB could provide relief from sleep dysfunction. This report implies that the
arousal level can be diminished by SGB. Since LISG including Xe-LISG provides therapeutic effects similar to SGB\(^3\)\(^{–}\)\(^7\)\(^{,}\)\(^10\), the arousal level may be diminished by Xe-LISG. Empirically, it is not surprising that a diminished arousal level causes instability during standing. Thus, in future studies, the arousal level during Xe-LISG should be investigated.

The present study has some limitations. First, this study evaluated instability during standing just after Xe-LISG only from a static viewpoint: the stabilometer measurement of quiet standing. Clinically, some patients often have to stand up and walk just after Xe-LISG to undergo other medical treatment. In subsequent studies, therefore, a test task related to standing-up and walking, such as the timed “Up & Go” test\(^{21}\), should also be used to evaluate the ability to maintain standing after Xe-LISG. Second, this study was limited to young subjects. In clinical practice, however, most patients who undergo Xe-LISG are the middle-aged and elderly. Future studies should reveal whether Xe-LISG can affect the ability to maintain standing in the middle-aged and elderly.

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