Uniformity in dynamic baroreflex regulation of left and right cardiac sympathetic nerve activities

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Uniformity in dynamic baroreflex regulation of left and right cardiac sympathetic nerve activities. *Am J Physiol Regul Integr Comp Physiol* 284: R1506–R1512, 2003. First published February 6, 2003; 10.1152/ajpregu.00736.2002.—Functional laterality of cardiac sympathetic nerve stimulation in chronotropic and inotropic effects is well known. Whether left (LSNA) and right (RSNA) cardiac sympathetic nerve activities show laterality during dynamic baroreflex activation remains to be determined. In nine anesthetized, vagotomized, and aortic-denervated rabbits, we randomly perturbed intracarotid sinus pressure (CSP) in both carotid sinus regions while simultaneously recording LSNA and RSNA. The baroreflex neural arc transfer function from CSP to LSNA and from CSP to RSNA revealed derivative characteristics, i.e., the magnitude of LSNA and RSNA responses became greater as the input frequency of CSP perturbation increased. The average slope of increasing gain in the frequencies between 0.03 and 0.3 Hz showed no difference between LSNA and RSNA responses (9.7 ± 2.9 vs. 9.7 ± 3.1 dB/decade, means ± SD). The amplitude ratio and phase difference between LSNA and RSNA responses (9.7 ± 3.1 vs. 9.7 ± 3.1 dB/decade, means ± SD). The magnitude of LSNA and RSNA responses became greater as the input frequency of CSP perturbation increased. The average slope of increasing gain in the frequencies between 0.03 and 0.3 Hz showed no difference between LSNA and RSNA responses (9.7 ± 2.9 vs. 9.7 ± 3.1 dB/decade, means ± SD). The amplitude ratio and phase difference between LSNA and RSNA responses (9.7 ± 3.1 vs. 9.7 ± 3.1 dB/decade, means ± SD). The magnitude of LSNA and RSNA responses became greater as the input frequency of CSP perturbation increased.

Although Ninomiya et al. (21) reported no detectable difference in left cardiac SNA (LSNA) and right cardiac SNA (RSNA) in response to epinephrine-induced arterial pressure (AP) input, we think that the study was incomplete with respect to the following points. First, the quantitative description was not made to what extent LSNA and RSNA were similar. Second, because the rate of pressure changes critically affects the baroreflex responses (26), the epinephrine-induced AP input, where the rate of pressure change is uncontrollable exactly, is not a proper method for analyzing the ventricular innervation and by an indirect inotropic effect through changes in heart rate (HR) (17, 20). In contrast, electrical stimulation of the left cardiac sympathetic nerve increases $E_{es}$ mainly through direct inotropic effect. The functional laterality of the sympathetic effects on the heart is evident in not only static but also dynamic regulation of HR and $E_{es}$ (18). Complex innervation patterns of the left and right cardiac sympathetic nerves, which would underlie the functional laterality, have been described in detail (23). The putative laterality of cardiac innervation patterns, however, becomes less evident when decentralized stellate or middle cervical ganglia are investigated (22).

Regional differences in sympathetic nerve activity (SNA) are considered to have physiological significance for the individualized regulation of target organs (21). Dynamic baroreflex regulation of SNA shows derivative characteristics (7). In other words, the magnitude of SNA response becomes greater as the input frequency of baroreceptor pressure perturbation increases. In our previous study, cardiac SNA and renal SNA showed different derivative characteristics, suggesting that dynamic baroreflex regulation differed among sympathetic nerves (11). As the functional laterality of cardiac sympathetic nerves resulted in different ventricular performance in response to electrical stimulation of the left- and right-sided neuronal structures (18), it is possible that the dynamic baroreflex regulation of cardiac sympathetic nerves differs between the left and right sides to effectively control cardiac function.

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input-output relationship of the baroreflex system. Finally, despite the importance of the dynamic characteristics of the baroreflex system in stabilizing AP (7), the study did not deal with dynamic baroreflex regulation of SNA. To extend the study by Ninomiya et al. (21), more sophisticated analysis of the baroreflex regulation of LSNA and RSNA is mandatory. Accordingly, the present study was designed to test the hypothesis that the dynamic baroreflex regulation differs between LSNA and RSNA. We performed a baroreflex open-loop experiment while recording LSNA and RSNA simultaneously in anesthetized rabbits. The results obtained indicated that no laterality existed in dynamic or static baroreflex regulation of cardiac sympathetic nerves as far as grouped axonal activity was concerned.

MATERIALS AND METHODS

Surgical Preparations

Animals were cared for in strict accordance with the Guiding Principles for the Care and Use of Animals in the Field of Physiological Sciences approved by the Physiological Society of Japan. Nine Japanese white rabbits weighing 2.6 to 3.2 kg were anesthetized via intravenous injection (2 ml/kg) of a mixture of urethane (250 mg/ml) and α-chloralose (40 mg/ml) and were mechanically ventilated with oxygen-enriched room air. The rabbits were slightly hyperventilated to suppress chemoreflexes (PaCO2 ranged from 30 to 35 mmHg, PaO2 > 400 mmHg). Arterial blood pH, examined at the end of surgical preparation and at the end of experiment, was within the physiological range. Supplemental anesthetics were injected as necessary (0.5 ml/kg) to maintain an appropriate level of anesthesia. Body temperature of the animal was maintained at 38°C with a heating pad. AP was measured using a high-fidelity pressure transducer (Millar Instruments) inserted via the right femoral artery into the thoracic aorta. We isolated the bilateral carotid sinus nerves vascularily from the systemic circulation by ligating the internal and external carotid arteries and other small branches originating from the carotid sinus regions. The isolated carotid sinus nerves were filled with warmed physiological saline through catheters inserted via the common carotid arteries. The intracarotid sinus pressure (CSP) was controlled by a servo-controlled piston pump. Both carotid sinus nerves were subjected to the same pressure changes. Bilateral vagal nerves and aortic depressor nerves were sectioned at the middle of the neck to avoid the afferent signals from the cardiopulmonary region and the aortic arch having influenced on the central processing of the carotid sinus baroreflex. However, this procedure could not exclude the effects of intrathoracic reflexes on cardiac SNA (3).

Multifiber Preparations

Through a midline thoracotomy, the left common carotid and subclavian arteries were exposed around their origins from the aortic arch. The left inferior cardiac sympathetic nerve was identified between the left common carotid and subclavian arteries and was traced back to the left cervicothoracic ganglion. The nerve was ligated with a 5–0 suture at the region it descends behind the subclavian artery and was sectioned distal to the ligature. A small loop was made at the desheathed tip of a shielded stainless steel wire (Bioflex wire AS633, Cooner Wire), which was then attached to the nerve. A loop of another stainless steel wire was attached to the nerve adjacent to the first loop. A pair of the stainless steel wires was then served as a bipolar electrode. To insulate and secure the electrode, the nerve and electrode were covered with a mixture of silicone gel (Semicosil 932A/B, Wacker Silicones) and white petrolatum (Vaseline). The right subclavian artery and ascending aorta were exposed in the right thorax. The right inferior cardiac sympathetic nerve that descends behind the subclavian artery was identified in the thoracic cavity. This nerve was ligated at the regions where it courses ventral to the trachea with a 5–0 suture and was then sectioned distal to the ligature. A bipolar stainless steel wire electrode was attached to the nerve similarly to the left side. In most of the animals, sectioning the left inferior cardiac sympathetic nerve transiently lowered HR by less than 10 beats/min, whereas the successive sectioning of the right inferior cardiac sympathetic nerve transiently lowered HR by 30 to 50 beats/min. The preamplified nerve signal was band-pass filtered at 150–1,000 Hz. It was then full-wave rectified and low-pass filtered with a cut-off frequency of 30 Hz to quantify the nerve activity. Pancuronium bromide (0.3 mg/kg) was administered to prevent contamination of muscle afferent activity in the CSN recordings. At the end of the experiment, hexamethonium (50 mg/kg) was administered intravenously to confirm the disappearance of LSNA and RSNA, i.e., both activities were predominantly postganglionic.

Because we recorded grouped axonal activity, varied activities from individual axons in the nerve bundle could not be determined (2). Although we analyzed synchronous phasic activity generated by the majority of efferent axons, nonphasic activity or asynchronous activity may be buried in the phasic activity. In addition, the cardiac sympathetic nerve examined may have contained axons innervating pulmonary tissues. Such axonal components may be unresponsive to the baroreceptor pressure input. Therefore, the recorded LSNA and RSNA could not represent all of the individual axonal activities in the nerve bundle. Notwithstanding the above-mentioned limitation relating multifiber preparations, we think that examining the laterality of grouped axonal activity in cardiac sympathetic efferent nerves is useful for better understanding the baroreflex control over the heart.

Protocols

Dynamic protocol. CSP in both carotid sinuses was servo-controlled to follow AP until steady-state pressure was reached. After obtaining operating pressure (OP) at the steady state, we assigned CSP randomly to either high (OP − 20 mmHg) or low (OP − 20 mmHg) pressure every 500 ms according to a binary white noise sequence for 10 min (10, 11, 13). The input power spectra of CSP were reasonably flat up to 1 Hz. The upper frequency bound of the input perturbation was determined from the dynamic characteristics of the carotid sinus baroreflex determined from previous studies (7, 10, 11, 13). Because the total baroreflex showed low-pass characteristics and its dynamic gain at 1 Hz was less than one-tenth than at 0.01 Hz in rabbits, we focused on the dynamic characteristics in the frequencies below 1 Hz. Conversely, normal baroreceptor afferent activity has a dynamic pattern associated with the rising and falling phases of the beat-by-beat pressure pulse itself. Possible differences between LSNA and RSNA relating such pulsatile pressure input could not be assessed by the present protocol.

Static protocol. CSP was first decreased to 40 mmHg. After LSNA and RSNA responses reached steady state, CSP was increased stepwise from 40 to 160 mmHg at increments of 20 mmHg. Each pressure step was maintained for 60 s. We
recorded CSP, LSNA, RSNA, and AP at a sampling rate of 200 Hz using a 12-bit analog-to-digital converter. The data were stored on the hard disk of a dedicated laboratory computer system for later analysis.

**Data Analysis**

In the dynamic protocol, to estimate the neural arc transfer function of the carotid sinus baroreflex, we treated CSP as the input and LSNA or RSNA as the output of the system. The input-output data pairs were resampled at 10 Hz and segmented into eight sets of 50% overlapping bins of 1,024 data points each. For each bin, a linear trend was removed and a Hanning window was applied. We then performed fast Fourier transformation to obtain frequency spectra of the input [X(f)] and output [Y(f)] (4). We then ensemble averaged, over the eight bins, the power of the input [SXX(f)], power of the output [SYY(f)], and crosspower between the input and output [SYX(f)]. Finally, the transfer function [H(f)] from the input to output was estimated using the following equation (16).

\[
H(f) = \frac{S_{YX}(f)}{S_{XX}(f)}
\]

Hereafter in the present paper, \(H_L\) and \(H_R\) denote the transfer function from CSP to LSNA and that from CSP to RSNA, respectively. To quantify the linear dependence between the input and output signals in the frequency domain, a magnitude-squared coherence function [Coh(f)] was calculated using the following equation (16).

\[
\text{Coh}(f) = \frac{|S_{XX}(f)|^2}{S_{XX}(f)S_{YY}(f)}
\]

The coherence value ranges from zero to unity. A unity coherence indicates a perfect linear dependence between the input (changes in CSP) and output (grouped axonal activity of LSNA or RSNA) signals, whereas zero coherence indicates total independence between the two signals.

To compare the dynamic responses to CSP perturbation between LSNA and RSNA directly, the transfer function from LSNA to RSNA was calculated. In this context, the transfer function represented the amplitude ratio and the phase difference between LSNA and RSNA in the frequency domain.

In the static protocol, we performed a regression analysis for the four-parameter logistic function using input-output data pairs averaged from the last 10 s of each CSP level as follows (14).

\[
y = \frac{P_1}{1 + \exp[P_2(CSP - P_3)]} + P_4
\]

where \(y\) indicates the LSNA or RSNA value corresponding to each CSP level. \(P_1\) is a response range (i.e., the difference between the maximum and minimum values of \(y\)). \(P_2\) is a coefficient of gain. \(P_3\) is a midpoint of the operating range in the CSP axis. \(P_4\) is a minimum value of \(y\).

To compare the static responses to CSP perturbation between LSNA and RSNA directly, we performed a linear regression analysis on LSNA-RSNA data pairs. A coefficient of determination \(r^2\) was calculated from the following equation.

\[
r^2 = \frac{\sum_{i=1}^{n} [\text{LSNA}(i) - \text{LSNA}] [\text{RSNA}(i) - \text{RSNA}]^2}{\sum_{i=1}^{n} [\text{LSNA}(i) - \text{LSNA}]^2 \sum_{i=1}^{n} [\text{RSNA}(i) - \text{RSNA}]^2}
\]

where LSNA(i) and RSNA(i) indicate the LSNA and RSNA values averaged from the last 10 s of each CSP level, respectively. \(n\) represents the number of CSP steps in the static protocol. LSNA and RSNA indicate the mean values of LSNA(i) and RSNA(i), respectively. The goodness of fit \(q\) was assessed by the standard error of estimate divided by the range of RSNA using the following equation.

\[
q = \frac{\sum_{i=1}^{n} [\text{RSNA}_{\text{est}}(i) - \text{RSNA}(i)]^2}{n - 2 \sum_{i=1}^{n} [\text{RSNA}(i) - \text{RSNA}]^2 \left(1 - r^2\right)}
\]

where \(\text{RSNA}_{\text{est}}(i)\) is a linear estimate of RSNA(i) from LSNA(i). \(\text{RSNA}_{\text{max}}\) and \(\text{RSNA}_{\text{min}}\) represent the maximum and minimum values of RSNA(i), respectively. \(q\) approaches zero with increasing accuracy of estimation.

**Statistical Analysis**

All data are presented as means ± SD. In all following statistics, differences were considered significant at \(P < 0.05\). As the magnitude of SNA varied depending on recording conditions, LSNA and RSNA are presented in arbitrary units (AU). In the dynamic protocol, we normalized \(H_L\) and \(H_R\) by the gain values averaged below 0.03 Hz, respectively. To examine the difference between \(H_L\) and \(H_R\), we used the gain and phase values at 0.01, 0.1, 0.5, and 1 Hz in each animal. After obtaining the gain and phase values at each frequency, group differences between \(H_L\) and \(H_R\) were examined by paired t-test (6). We also calculated an average slope of the transfer gain in the frequencies between 0.03 and 0.3 Hz in each animal and examined its group difference between \(H_L\) and \(H_R\) by paired t-test.

In the static protocol, because the \(P_1\) and \(P_4\) values could be matched between CSP-LSNA and CSP-RSNA curves by arbitrarily scaling of LSNA and RSNA, we compared only the \(P_2\) and \(P_3\) values by paired t-test (6). Note that the \(P_2\) value has a reciprocal relationship with the width of operating range \((P_{\text{range}})\) in the CSP axis independent of the other parameters as follows.

\[
P_{\text{range}} = P_{\text{sat}} - P_{\text{th}} = \frac{2k}{P_0}
\]

where \(P_{\text{th}}\) and \(P_{\text{sat}}\) denote the threshold and saturation pressure, respectively. \(k\) is a constant for calculating the threshold and saturation points. We used \(k = 1.317\) according to the model by Kent et al. (14).

**RESULTS**

Figure 1 shows the typical time series of CSP, LSNA, RSNA, and AP. CSP was perturbed with a binary white noise sequence. When CSP was increased, both LSNA and RSNA decreased. When CSP was decreased, the opposite responses were observed. Although each discharge pattern between LSNA and RSNA did not match exactly, general dynamic responses were similar between the two activities. Changes in AP did not affect CSP in the present experimental settings, validating the application of a conventional open-loop transfer function analysis (9, 12, 16).
Figure 2 depicts averaged $H_L$ and $H_R$ from all animals. Gain plots (top), phase plots (middle), and coherence functions (bottom) are shown. The gain value approximated unity at the lowest frequency in both $H_L$ and $H_R$ because of the normalization procedure. The gain values increased as the input frequency of CSP increased between 0.03 and 0.3 Hz, indicating derivative characteristics of the neural arc. The slope of the increasing transfer gain was similar between $H_L$ and $H_R$. The phase plots indicated an out-of-phase relationship between the input and output signals below 0.2 Hz, reflecting negative feedback attained by the baroreflex neural arc. The coherence functions associated with $H_L$ and $H_R$ showed no marked difference.

Table 1 summarizes the parameters of the neural arc transfer functions. Neither gain nor phase values differed between $H_L$ and $H_R$ at 0.01, 0.1, 0.5, and 1 Hz. The slope of increasing dynamic gain showed no difference between $H_L$ and $H_R$.

Figure 3 shows the amplitude ratio and phase difference between LSNA and RSNA during the dynamic protocol. The amplitude ratio of RSNA to LSNA approximated unity in the frequencies between 0.01 and 1 Hz. The phase difference between LSNA and RSNA approximated zero radians over the frequency range under study. The coherence values between LSNA and RSNA were above 0.9 in the frequencies below 0.1 Hz and near unity above 0.1 Hz.

Figure 4 presents typical results obtained from the static protocol. Figure 4A shows the time series of CSP, LSNA, and AP during the dynamic protocol. CSP was changed according to a binary white noise signal. Data were resampled at 10 Hz for this panel. a.u., Arbitrary units.

**Table 1. Parameters of the neural arc transfer function**

<table>
<thead>
<tr>
<th></th>
<th>$H_L$</th>
<th>$H_R$</th>
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</thead>
<tbody>
<tr>
<td>Gain, AU/mmHg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.01 Hz</td>
<td>0.99 ± 0.11</td>
<td>1.00 ± 0.08</td>
</tr>
<tr>
<td>0.1 Hz</td>
<td>2.18 ± 0.88</td>
<td>2.06 ± 0.79</td>
</tr>
<tr>
<td>0.5 Hz</td>
<td>4.17 ± 1.79</td>
<td>3.94 ± 1.56</td>
</tr>
<tr>
<td>1 Hz</td>
<td>3.76 ± 1.55</td>
<td>3.62 ± 1.55</td>
</tr>
<tr>
<td>0.1 Hz</td>
<td>−2.64 ± 0.24</td>
<td>−2.65 ± 0.20</td>
</tr>
<tr>
<td>0.5 Hz</td>
<td>−3.69 ± 0.20</td>
<td>−3.72 ± 0.21</td>
</tr>
<tr>
<td>1 Hz</td>
<td>−4.80 ± 0.23</td>
<td>−4.86 ± 0.25</td>
</tr>
<tr>
<td>Slope, dB/decade</td>
<td>0.03–0.3 Hz</td>
<td>0.03–0.3 Hz</td>
</tr>
</tbody>
</table>

Data are means ± SD. No statistical differences in each parameter. $H_L$, neural arc transfer function estimated using left cardiac sympathetic nerve activity; $H_R$, neural arc transfer function estimated using right cardiac sympathetic nerve activity.
LSNA, and RSNA. LSNA and RSNA decreased in response to the increments in CSP. Figure 4B illustrates the CSP-LSNA and CSP-RSNA relationships obtained from the last 10 s of each CSP level. The fitted logistic functions were superimposable by arbitrary scaling of the ordinate. The group averaged parameters of the coefficient of gain and the midpoint of the operating range did not differ between the CSP-LSNA and CSP-RSNA curves ($P_2: 0.125 \pm 0.049$ vs. $0.125 \pm 0.039$ AU/mmHg; $P_3: 110.2 \pm 13.1$ vs. $109.9 \pm 13.8$ mmHg). The width of the operating range derived from the $P_2$ values was $24.4 \pm 10.5$ mmHg for the CSP-LSNA curve and $23.2 \pm 7.7$ mmHg for the CSP-RSNA curve. Figure 4C illustrates the scattergram of RSNA vs. LSNA obtained from the same data as in Fig. 4B. The static LSNA-RSNA relationship approximated a straight line ($r^2 = 0.998$).

DISCUSSION

To our knowledge, the present study is the first to demonstrate that the arterial baroreflex regulation was indistinguishable between LSNA and RSNA in dynamic characteristics when grouped activity of whole nerve slips was examined. Despite the significant laterality in the chronotropic and inotropic responses to electrical stimulation of the cardiac sympathetic nerves, the carotid sinus baroreflex may not use the functional laterality of the sympathetic effects on the heart to optimize cardiac performance for dynamic AP regulation.

Dynamic Baroreflex Regulation of LSNA and RSNA

The baroreflex neural arc possesses derivative characteristics (7). That is to say, the magnitude of SNA response becomes greater as the input frequency of CSP perturbation increases. In our previous study (11), the extent of the derivative characteristics was more enhanced in cardiac SNA than renal SNA, suggesting a regional difference in dynamic baroreflex regulation of the sympathetic system. In contrast, the derivative characteristics assessed by the average slope of increasing gain did not differ between $H_L$ and $H_R$ (Fig. 2 and Table 1). Although interindividual differences caused the variances in the gain plots, $H_L$ and $H_R$ were almost superimposable in each animal. To compare the LSNA and RSNA responses directly, we calculated the amplitude ratio and phase difference between LSNA and RSNA in each animal and averaged them across all animals. The amplitude ratio was close to unity and the phase difference approximated zero radians (Fig. 3), suggesting the uniformity of dynamic LSNA and RSNA responses to CSP perturbation. The coherence function between LSNA and RSNA calculated from Eq. 2 approximated unity in the frequency under study (0.01–1 Hz). These findings suggest that LSNA and RSNA conveyed quite similar information during dynamic baroreflex activation in the input frequency range under study. The interindividual differences in the derivative characteristics observed in the gain plot (Fig. 2) may be partly explained as follows. Because the carotid sinus isolation procedure could damage the baroreceptor afferent nerves to a variable extent, the effective amplitude of afferent signals to the brain stem might have been different among animals despite the same input amplitude of CSP. The difference in effective
input amplitude could lead to the different derivative characteristics due to the input-size dependency of the baroreflex neural arc transfer characteristics (13).

If the derivative characteristics of the baroreflex neural arc are totally ascribable to the baroreceptor transduction properties and what we observed in $H_L$ and $H_R$ are the simple reflection of the baroreceptor transduction properties, similarity between $H_L$ and $H_R$ might be a matter of course. However, the derivative characteristics of the neural arc from pressure input to sympathetic efferent nerve activity are more enhanced than those of the baroreceptor transduction alone, suggesting that the central processing plays an important role in determining the derivative characteristics (11, 27).

In a previous study, Ikeda et al. (8) demonstrated that instantaneous HR was successfully decoded from sympathetic efferent nerve activity in anesthetized rabbits. In that study, LSNA was used as the input for the HR prediction. Because HR could be predicted from LSNA using a transfer function analysis as long as HR was explained by linear dynamics with LSNA, the uniformity between LSNA and RSNA is not a prerequisite for HR prediction. However, the uniformity between LSNA and RSNA may have contributed to the successful prediction of HR in respect to the following. If the frequency bandwidth of the LSNA response had been much narrower than that of the RSNA response, the precise prediction of HR from LSNA alone might have been impossible.

Limitations

There are several limitations to this study. First, because we recorded multifiber activities of cardiac sympathetic nerves, differences in single fiber activity among the nerve bundle were not assessed. However, functional laterality is evident even when the whole bundle of nerves is electrically stimulated, suggesting that population differences exist in nerve fibers related to the chronotropic and inotropic effects between the left and right cardiac sympathetic nerves.

Second, we sectioned the vagal nerves to simplify our system identification. Because the vagal efferent nerves participate in the chronotropic and inotropic effects on the heart (19), further studies are required to clarify whether the baroreflex control differs between the left and right vagal nerve activities.

Third, most of the previous descriptions of functional laterality of cardiac sympathetic nerves have been obtained from the dog. In the cat, activation of the right rostral ventral lateral medulla (RVLM) caused a HR increase greater than activation of the left RVLM (5). Although we usually observed a marked HR decrease only after sectioning the right inferior cardiac sympathetic nerve in the present study, we did not directly assess the functional laterality of the cardiac sympathetic nerves. Further studies are required to elucidate to what degree the rabbit shows functional laterality of cardiac sympathetic nerves as compared with the more commonly studied dog.

Finally, we filled the isolated carotid sinuses with warmed physiological saline. As the ionic content affects the sensitivity of the baroreceptors (2), the absolute gain values of the carotid sinus baroreflex might have differed from normal physiological values. However, because we perturbed CSP without changing intravascular ion content, LSNA and RSNA responses should mainly result from changes in CSP.

In conclusion, uniformity in the dynamic as well as static baroreflex regulation of LSNA and RSNA was identified. The carotid sinus baroreflex may not use the functional laterality of the cardiac sympathetic efferent nerves to optimize cardiac performance for AP regulation. The significance of the neural regulation on the heart compared with humoral regulation appears to be the speed of its action rather than the differential regulation of the chronotropic and inotropic effects on the heart.

Perspectives

We could not identify any laterality in cardiac SNA during carotid sinus baroreflex activation in the present experimental settings. However, the cardiovascular reflexes including the intrathoracic reflexes are also known to control cardiac SNA (3). Because such reflexes can be activated by local stimuli associated with acute myocardial ischemia and infarction, some functional lateralization of cardiac SNA might manifest under such pathological conditions. Differences in species and experimental conditions may also influence the degree of uniformity in the grouped axonal activity between LSNA and RSNA. Whether the functional laterality of the cardiac sympathetic nerves has teleological significance awaits further investigations.

This study was supported by Research Grants for Cardiovascular Diseases (11C-3, 11C-7) from the Ministry of Health and Welfare of Japan, by a Health Sciences Research Grant for Advanced Medical Technology from the Ministry of Health and Welfare of Japan, by a Ground-Based Research Grant for Space Utilization promoted by National Space Development Agency of Japan and the Japan Space Forum, by Grant-in-Aid for Scientific Research (B-11694337, C-11680869, C-11670730) and Grant-in-Aid for Encouragement of Young Scientists (13770378) from the Ministry of Education, Science, Sports and Culture of Japan, by Research and Development for Applying Advanced Computational Science and Technology from the Japan Science and Technology Corporation, and by the Program for Promotion of Fundamental Studies in Health Science from the Organization for Pharmaceutical Safety and Research.

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