Changes in Blood Pressure and Heart Rate Variability During Dental Surgery

Kiyoshi Matsumura, Keiko Miura, Yutaka Takata, Hideo Kurokawa, Minoru Kajiyama, Isao Abe, and Masatoshi Fujishima

The objective of the present study was to determine the changes in blood pressure, pulse rate, and heart rate variability during dental surgery. The study included 40 patients, 19 to 74 years of age (mean age: 42.7 ± 3.0 years), who underwent tooth extraction at our hospital. Holter electrocardiographic monitoring was used to determine the power spectrum of R-R variability before and during dental surgery. The low frequency (LF: 0.041 to 0.140 Hz), high frequency (HF: 0.140 to 0.500 Hz), and total spectral powers (TF: 0.000 to 4.000 Hz) were calculated, and the ratio of LF to HF and percentage of HF relative to TF (%HF: HF/TF × 100) were used as indices of sympathetic and parasympathetic activities, respectively. The baseline blood pressure and pulse rate were 121 ± 3/70 ± 2 mm Hg and 70 ± 1 beats/min, respectively. After the administration of local anesthetic (2% lidocaine) containing 1:80,000 epinephrine, both the blood pressure and pulse rate increased. During dental surgery, blood pressure increased further to 132 ± 3/73 ± 2 mm Hg. The increase in blood pressure was greater in middle-aged and older patients (>40 years old). In young patients (<40 years old), the %HF decreased and the LF/HF increased during local anesthesia. In contrast, in middle-aged and older patients, the LF/HF decreased during local anesthesia. These results suggest 1) that middle-aged and older patients have a greater increase in blood pressure during dental surgery than younger patients, and 2) that the regulation of the autonomic nervous system during dental surgery differs between younger and older patients. Am J Hypertens 1998; 11:1376–1380 © 1998 American Journal of Hypertension, Ltd.

KEY WORDS: Age, blood pressure, dental surgery, heart rate variability, sympathetic nervous system.
nervous system activity during dental surgery have not been fully elucidated.

Power spectral analysis of R-R variability has been widely used to evaluate the sympathetic and parasympathetic contribution to the heart. Although blood pressure and heart rate increase during dental surgery, it is not known whether sympathetic outflow to the heart increases. Therefore, the present study was designed to determine the effect of dental surgery on blood pressure and heart rate variability.

SUBJECTS AND METHODS
The study included 40 patients (19 to 74 years old; mean age: 42.7 ± 3.0 years; 14 men and 26 women) who underwent tooth extraction at Kyushu Dental College. To determine the effect of age on blood pressure and heart rate variability, the patients were divided into two groups: young patients (<40 years; n = 20), and middle-aged and older patients (≥40 years; n = 20). The details of the protocol were explained to the patients, and written informed consent was obtained. On the day of dental surgery, each patient was asked to complete a questionnaire concerning medical history and medication use. After recording a 12-lead electrocardiogram, continuous two-channel Holter electrocardiographic monitoring was performed and recorded on tape (SM-50, Fukuda Denshi, Tokyo, Japan). The patients were kept in a supine position for ≥10 min in a quiet room, and blood pressure and pulse rate were measured every 2 min by the oscillometric method using an automatic device (BP-203i, Nippon Colin, Komaki, Japan). The average of the last two measurements was defined as the baseline blood pressure and pulse rate. The patients were then moved to the dental department to undergo tooth extraction. The patients were kept in a supine position during the entire procedure. Local anesthesia was administered after a control period of at least 10 min. Lidocaine, 2% with epinephrine (1:80,000), was used as an anesthetic for all of the patients. Surgery was begun 10 min after injection of the local anesthetic. After surgery, the patients were kept in a supine position during a recovery period of at least 10 min. Blood pressure and pulse rate were measured every 2 min throughout the study. Blood pressure and pulse rate were averaged in each patient during each treatment period (before surgery, during local anesthesia, during surgery, and after surgery). To eliminate the effects of the duration of the surgery or the volume of local anesthetic administered, we analyzed the initial 10 min of the dental surgery.

Power Spectral Analysis of R-R Intervals Two-channel electrocardiographic monitoring was performed to record R-R intervals on magnetic tape. The R-R intervals that were recorded on magnetic tape were converted to digital signals (SCM-3000 System, Fukuda Denshi), and periods of 256 sec were sampled for further analysis. The autoregressive parameters were then calculated, and power spectral densities were computed using the maximum entropy method with a commercially available program (HPS-RRA version 2.01, Fukuda Denshi). The power spectrum was divided into the low frequency (LF) band (0.041 to 0.140 Hz), which is an index of both sympathetic and parasympathetic activity, and the high frequency (HF) band (0.140 to 0.500 Hz), which reflects parasympathetic activity. Total frequency (TF) was defined as the frequency range from 0.000 to 4.000 Hz. The ratio of LF to HF, which is an index of sympathovagal balance, was calculated. The percentage of HF relative to TF (%HF) was calculated as HF/TF × 100. These frequency components were calculated for each patient in each time period between 5 and 10 min before surgery, during administration of local anesthesia, during surgery, and after surgery.

Statistics All values are expressed as the mean ± SE. To analyze the effects of local anesthesia and dental surgery on blood pressure and heart rate variability, a paired t test was used to determine which means were significantly different from the baseline values. P values < .05 were considered statistically significant.

RESULTS
Table 1 summarizes the clinical characteristics of the patients. The main reasons for tooth extraction were pericoronitis in the young patients (<40 years; n = 20) and periodontitis in the middle-aged and older patients (≥40 years; n = 20). Six patients had hypertension based on World Health Organization (WHO) criteria, and three of them were taking antihypertensive drugs (diuretics and/or calcium channel antagonists). The average blood pressure and pulse rate for all of the patients were 121 ± 3/70 ± 2 mm Hg and 70 ± 1 beats/min, respectively. Administration of local anesthetics and tooth extraction caused increases in both systolic blood pressure and pulse rate, and the peak systolic blood pressure occurred during tooth extraction (132 ± 3 mm Hg, P < .01). However, diastolic blood pressure did not change significantly during the entire treatment period. Middle-aged and older patients had higher blood pressures and lower pulse rates compared with young patients (Table 1). The top and middle panels of Figure 1 illustrate the changes in systolic blood pressure and pulse rate in the two age groups. The change in systolic blood pressure was greater in middle-aged and older patients than in young patients.

The lower panel of Figure 1 shows the time course for LF/HF elicited by administration of local anesthetic and tooth extraction in the two groups. The
LF/HF increased during the administration of local anesthesia in young patients; however, the middle-aged and older patients had the opposite response. In contrast, the %HF decreased in both groups during the administration of local anesthesia, although the decrease in %HF was greater in young patients than in middle-aged and older patients. Furthermore, the change in LF/HF caused by the administration of local anesthetic was negatively correlated with age (Figure 2). During dental surgery, both %HF and LF/HF returned to the pretreatment values in both groups.

**DISCUSSION**

To the best of our knowledge, this is the first study to determine the Holter electrocardiographic monitoring and the power spectral analysis of R-R variability during dental surgery. Many patients who visit dental clinics have systemic diseases such as hypertension, ischemic heart disease, and other atherosclerotic diseases. In one study, 64% of the elderly patients who visited the dental clinic were found to have one or more systemic diseases, and among them hypertension was the most frequent systemic disease, occurring in ≈30% of the patients.1 Furthermore, cardiovascular accidents caused by hypertension during dental surgery have also been reported.11 It is therefore important to determine the responses of blood pressure and sympathetic outflow during dental surgery. Before conducting the present study, we hypothesized that LF/HF, which reflects sympathetic nervous system activity, would increase during dental surgery, as a result of painful stimuli, psychological stress, or the epinephrine contained in the local anesthetic. The increased sympathetic activity would therefore increase blood pressure and pulse rate. However, in the present study, only young patients had an increase in LF/HF during the administration of local anesthesia, but not during the dental surgery. In contrast, middle-aged and older patients had a decrease in LF/HF during the administration of local anesthesia. This divergent response in LF/HF between younger and older patients after the administration of local anesthetics was associated with a negative correlation between age and the change in LF/HF (Figure 2). Furthermore, the %HF, which reflects parasympathetic activity, decreased significantly (P < .01) during the administration of local anesthesia only in the young patients. These results suggest that the responses and the regulation of the autonomic nervous system between younger and older patients are different during dental surgery.

It is difficult to account for the paradoxical blood pressure and LF/HF responses during local anesthesia in middle-aged and older patients. The function and the regulation of the autonomic nervous system are impaired in elderly patients, which might explain this paradoxical response during the administration of local anesthesia. Furthermore, the middle-aged and older patients had a greater increase in blood pressure during dental surgery, although the LF/HF did not increase. Therefore, it is unlikely that the greater blood pressure response was due to enhanced sympathetic activity in the hearts of the older patients. The paradoxical blood pressure and LF/HF responses may be due to the atherosclerotic changes and augmented vascular reactivity in older patients.

The peak change in LF/HF and %HF occurred during the administration of local anesthesia. However, the peak systolic blood pressure response was observed during surgery. Local anesthetic solutions containing epinephrine have been shown to increase plasma epinephrine concentrations, although the effects of these solutions on blood pressure and heart rate responses have been controversial. Köhler-Knoll

### TABLE 1. CLINICAL CHARACTERISTICS OF THE SUBJECTS

<table>
<thead>
<tr>
<th></th>
<th>All</th>
<th>Young</th>
<th>Middle-Aged and Older</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>40</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Age (years)</td>
<td>42.7 ± 3</td>
<td>26.1 ± 1.4</td>
<td>59.4 ± 2.4</td>
</tr>
<tr>
<td>Sex (M/F)</td>
<td>14/26</td>
<td>9/11</td>
<td>5/15</td>
</tr>
<tr>
<td>Hypertension</td>
<td>6</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Antihypertensive treatment</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Baseline SBP (mm Hg)</td>
<td>121 ± 3</td>
<td>116 ± 3</td>
<td>127 ± 5</td>
</tr>
<tr>
<td>Baseline DBP (mm Hg)</td>
<td>70 ± 2</td>
<td>67 ± 2</td>
<td>74 ± 3</td>
</tr>
<tr>
<td>Baseline PR (beats/min)</td>
<td>70 ± 1</td>
<td>72 ± 2</td>
<td>67 ± 1</td>
</tr>
<tr>
<td>Reasons for tooth extraction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pericoronitis</td>
<td>18</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>periodontitis</td>
<td>10</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>stump tooth</td>
<td>10</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Others</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Values are mean ± SE.

SBP, systolic blood pressure; DBP, diastolic blood pressure; PR, pulse rate.
et al\textsuperscript{7} have demonstrated that the catecholamine present in local anesthetics caused an increase in blood pressure. However, Davenport et al\textsuperscript{12} and Salonen et al\textsuperscript{13} were unable to show such an increase. Because we did not measure plasma catecholamine concentrations in the present study, it was difficult to determine systemic sympathetic activity quantitatively during the dental surgery. However, it is unlikely that the LF/HF response was mediated only by the direct effect of the epinephrine present in the local anesthetic, because plasma epinephrine concentrations remain high 30 min after administration.\textsuperscript{13} Therefore, the combined effects of factors including painful stimuli and psychological stress and the direct effect of epinephrine contained in the local anesthetics might elicit a greater sympathetic response.

Relatively few hypertensive patients were included in the present study. In the preliminary analysis of the changes in blood pressure and heart rate variability responses between normotensive and hypertensive patients. Previous studies have suggested that the increment of blood pressure during dental procedures is greater in hypertensive patients than in normotensive patients.\textsuperscript{3} However, changes in heart rate variability during dental surgery in hypertensive patients have not been described. Previous studies from our laboratory suggest that the blood pressure response depends on the length of surgery or the volume of local anesthetic administered.\textsuperscript{6} To avoid the effects of the length of the surgery, measurements were obtained during the initial 10 min of the operative period. Hypertension may cause a greater increase in blood pressure later in the dental surgery. Further study will be required to determine the changes in blood pressure and heart rate variability in hypertensive patients during dental surgery.

The rate-pressure product, which is the product of the systolic blood pressure and the heart rate, has been used to estimate myocardial oxygen consumption. In the present study, both systolic blood pressure and heart rate increased significantly during the dental surgery, resulting in an increase in the rate-pressure product. Myocardial oxygen consumption should therefore increase during dental surgery. Although none of the patients in the present study complained of chest pain or had significant ST-T changes, ST-T changes during dental surgery have been reported in patients with coronary artery disease.\textsuperscript{14,15} Because tooth extraction can increase myocardial oxygen consumption and induce myocardial ischemia, careful
electrocardiographic monitoring should be performed in patients with coronary artery disease.

In conclusion, dental surgery using local anesthesia caused significant increases in systolic blood pressure and pulse rate, and the increase in systolic blood pressure was greater in middle-aged and older patients. The LF/HF determined by power spectral analysis of R-R variability increased during the administration of local anesthesia only in young patients. However, it was not related to the increase in blood pressure. Factors other than the sympathetic input to the heart contribute to the increase in blood pressure during dental surgery.

REFERENCES