Heart rate variability

A sensitive parameter for detecting abnormal cardiocirculatory changes during a stressful dental procedure

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Most dental treatments are associated with a strong cardiovascular reaction, which usually is harmless in healthy subjects, but could be highly deleterious in susceptible patients with heart disease.[1,2]

Acute psychological stress, such as that experienced in a dental operation, elicits a defense reaction characterized by a marked increase in sympathetic nerve activity, which may, in patients with advanced heart failure, trigger adverse cardiac events.[3,4] To promptly interrupt a dental procedure before a life-threatening cardiovascular event takes place, clinicians need a parameter for the early detection of an exaggerated increase in heart activity due to an exaggerated sympathetic drive.

Heart rate variability is a highly sensitive parameter for quantifying the sympathetic drive to the heart.

Blood pressure, or BP, and heart rate, or HR, are used commonly as indirect indexes of increased sympathetic activity during stress; however, research has not demonstrated the actual validity of these parameters in the early detection of abnormal cardiocirculatory changes that could occur in cardiac emergencies.[5-7] In fact, HR and BP patterns during a stressful situation depend on the typical reaction of the individual in the situation.[8]

A prevalent increase in peripheral vascular resistance in some people typically elicits a sustained increase in BP, which is responsible for a decline in HR via baroreflex-mediated mechanisms, while a prevalent increase in cardiac reaction in other people typically produces an increase in HR along with a decline in BP.[9,10]

ABSTRACT

Background. The authors conducted a study to evaluate the sensitivity of heart rate variability, or HRV, in quantifying the cardiocirculatory reaction to dental stress compared with other clinical parameters more frequently used in clinical practice.

Methods. Twenty-five healthy subjects (15 men and 10 women aged 19 through 73 years) who underwent dental extractions were enrolled in the study. The authors measured systolic blood pressure, or SBP; diastolic blood pressure, or DBP; heart rate, or HR; and HRV at baseline, immediately after local anesthetic was administered, during the dental extraction and five minutes after the dental extraction. Time domain measures of HRV were based on interbeat intervals and were obtained by using standard deviations of the R-R intervals, which were calculated during a five-minute period in a continuous electrocardiographic record.

Results. Analysis of variance for repeated measures showed no time-related difference between the four study periods with regard to SBP and DBP. However, HR values were significantly different in three of the four periods, and HRV values were significantly different in all four testing periods. Furthermore, HRV values exhibited greater variability in the maximum changes recorded during dental extractions compared with HR values (0 to 80 milliseconds versus 0 to 31 beats/minute, respectively).

Conclusions. HRV is a highly sensitive parameter for quantifying the sympathetic drive to the heart during a cardiovascular reaction to a dental operation.

Clinical Implications. Clinicians may find that HRV evaluation is useful in monitoring patients with heart disease to detect early signs of cardiac impairment related to local, high sympathetic activity and to prevent cardiovascular emergencies.

It follows that HR and BP taken alone or together should not be considered reliable indexes for quantifying cardiovascular activity during stress, because they frequently interact with each other and are inversely correlated.

Investigators have identified heart rate variability, or HRV, as one of the most promising markers of cardiovascular activity.[11,12] The assessment of HRV is based on the analysis of consecutive sinus rhythm R-R intervals (beat-to-beat) and may provide quantitative information about the modulation of cardiac vagal and sympathetic nerve activities to the heart.[13]

Low HRV values indicate elevated sympathetic myocardial activity and an increased risk of malignant dysrhythmias, particularly in patients with heart disease.[14-16]

Researchers have demonstrated that HRV is affected strongly by a stressful situation such as a dental appointment, and have suggested that it could be a sensitive quantitative marker of autonomic activity during stress.[17,18]

The objective of this study was to evaluate the sensitivity of HRV in quantifying the cardiocirculatory reaction during a dental extraction in comparison with other clinical parameters more frequently used in clinical practice.

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SUBJECTS, MATERIALS AND METHODS

During the first six months of 2003, we enrolled 25 consecutive healthy subjects (15 men and 10 women aged 19 through 73 years; mean [± standard deviation] age, 40.3 ± 5.0 years) who underwent a dental extraction at the Department of Oral Science, University of Bologna, Italy.

All subjects were free of any cardiovascular or systemic diseases (a trained cardiologist carefully assessed their medical histories, and noted the absence of any hospitalization for cardiovascular events) and were not currently taking any medication. Before entering the study, all patients underwent 12-lead electrocardiography to rule out any supraventricular or ventricular dysrhythmia. After being informed of the purpose of the study, the patients signed an informed consent form.

All teeth that were to be extracted had no vestibular-lingual mobility, and a dentist (not one of the authors) performed all of the extractions in the morning, with the patient in a sitting position.

We recorded the following information for all subjects:

- HR;
- systolic blood pressure, or SBP, and diastolic blood pressure, or DBP, via an automatic, noninvasive device;
- HRV, which assesses the interbeat fluctuations (cycle length variability), via an automatic device (Castellini S.p.A., Bologna, Italy). We obtained time domain measures of HRV by using standard deviations of the R-R interval (that is, the square root of variance calculated during a five-minute period).

We assessed each parameter in all subjects (who were in a sitting position) after five minutes of relaxation (basal), immediately after the administration of the local anesthetic (mepivacaine 2 percent with adrenaline 1:100,000) (postanesthesia), three minutes after the beginning of the dental extraction (extraction) and five minutes after completion of the dental extraction (recovery).

STATISTICAL ANALYSIS

For the statistical analysis, we fitted a general linear model and used multiple regression analysis of variance for repeated measures to evaluate time-dependent differences in SBP, DBP, HR and HRV during all four periods. We used Fisher's least significant difference test to discriminate among the means. In addition, we evaluated the time-dependent differences in HRV after adjusting the model for HR and age of the patients as covariates to determine whether the final results could be influenced by these parameters.[19]

RESULTS

Figures 1 and 2 illustrate the changes in BP during dental surgery. No significant time-dependent changes were demonstrated in SBP or DBP.

The HR time-course analysis made it possible to differentiate mean HR values recorded during the dental extraction and recovery periods from basal values, but it failed to differentiate basal values from values recorded immediately after administration of the local anesthetic (Figure 3, page 1721). Furthermore, we recorded a narrow range (0 to 31 beats/minute) of maximum changes in HR (compared with basal values) in all sub-

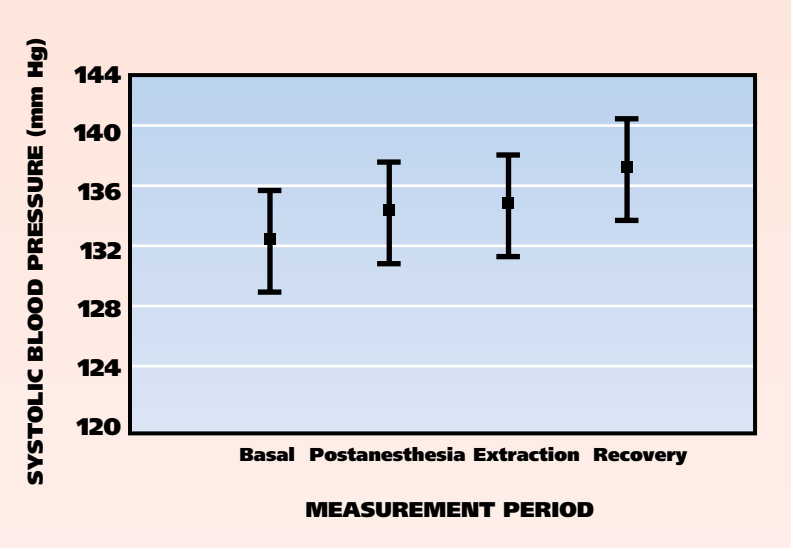

Figure 1. Time-dependent variation in systolic blood pressure (mean ± 95 percent least significant difference intervals) during dental extractions. No significant differences between periods were found. F = .53. mm Hg: Millimeters of mercury.

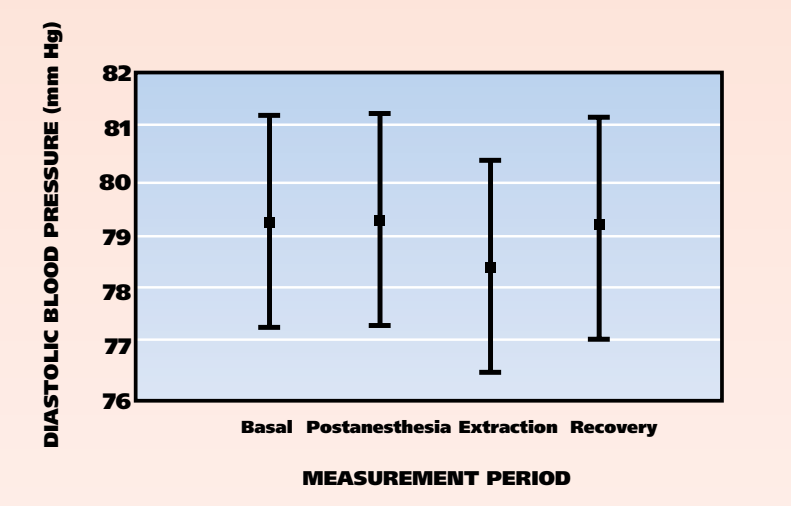

Figure 2. Time-dependent variation in diastolic blood pressure (mean ± 95 percent least significant difference intervals) during dental extractions. No significant differences between periods were found. F = .08. mm Hg: Millimeters of mercury.

jects during maximum stress.

Figure 4 shows the changes in HRV during dental surgery. The results show that HRV was highly able to differentiate between all four periods. The results obtained from the general linear model (after adjusting HRV values for HR and age of the patients) showed a very small difference in the F value (from 40.7 before adjusting for HR and age to 38.9 after adjusting for these variables) and no statistically significant difference according to Fisher's least significant difference test. In addition, we recorded a wide range (0 to 80 milliseconds) of maximum HRV changes (compared with basal values) in all subjects during maximum stress.

DISCUSSION

The cardiovascular reaction to a stressful situation is thought to be influenced by cardiac-vagal withdrawal and α-,β-adrenergic activation, resulting in increased cardiac chronotropic and inotropic influences (cardiac reaction), as well as in increased total peripheral resistance (vascular reaction). The final result is an increase in both HR and BP.[20]

However, the hemodynamics underlying cardiovascular reactions to mental stress tasks inevitably vary between people and between tasks as well.[8,21] People differ in the cardiac and vascular processes that underlie their cardiovascular response to a stressful situation, and they may be characterized by the extent to which their responses entail a predominant elevation in cardiac output (cardiac reactors) or peripheral resistance (vascular reactors).[8,22] It now is clear that some people are predominantly cardiac reactors and some are vascular reactors, and some tasks more often elicit cardiac reactions and others elicit vascular reactions.

These data suggest that, although a subject's hemodynamic reactions to behavioral stimuli vary, the variability between subjects is consistent.[20] It is possible that cardiac and vascular reactivity reflects individual differences in sympathoadrenal activation (epinephrine versus norepinephrine) during a stressful situation.

Elevated epinephrine levels. A predominant elevation of epinephrine levels compared with norepinephrine levels under psychological challenge likely will increase HR and cardiac output, by activating β-adrenergic receptors on the heart and β_2-adrenergic receptors on vascular smooth-muscle cells; this causes a hemodynamic response pattern reminiscent of that characterizing cardiac reactors (that is, a strong increase in HR and a slight or no increase in BP).[23]

Elevated norepinephrine levels. On the other hand, because of a high affinity for α-adrenergic receptors in the resistance vessels, norepinephrine produces a significant rise in BP, as a consequence of an increase in peripheral resistance, which triggers baroreflex-mediated (vagal) deceleration of the HR. Thus, an increase in norepinephrine levels during mental challenge would be expected to be associated with a strong elevation in BP and only a slight elevation in HR, which is the hemodynamic pattern characterizing vascular reactors.[24]

Researchers also have demonstrated that the hemodynamic patterns undergo significant changes in people during stress exposure; over time, people exhibit a sustained arterial pressure response, owing to a continuous increase in peripheral resistance, and a declining cardiac response (namely, HR), owing to a progressive reduction in the cardiac inotropic influence.[25,26] Thus, the extent of HR and BP increases during a stressful situation depends on an individual's typical reaction during the stress task.

A prevalent increase in peripheral vascular resistance typically elicits a sustained BP, which is responsible for a decline in HR (via baroreflex-mediated mechanisms), while a prevalent increase in cardiac reaction typically produces an increase in HR compared with BP.

In 2001, Lawler and colleagues[21] identified six hemodynamic reactor patterns in a group of 203 subjects undergoing similar stress tasks. The authors reported quite different BP and HR fluctuations among the subjects during stress. It follows then that HR and BP taken alone or together are not reliable indexes for precisely quantifying the cardiovascular reaction to stress, because they frequently interact with each other and are inversely correlated.

In accordance with this hypothesis, the results of our study show that BP is not a sensitive parameter for quantifying cardiovascular reaction in a population of people undergoing a dental operation, because it was not able to differentiate between any of the four periods examined (that is, basal, postanesthesia, extraction and recovery).

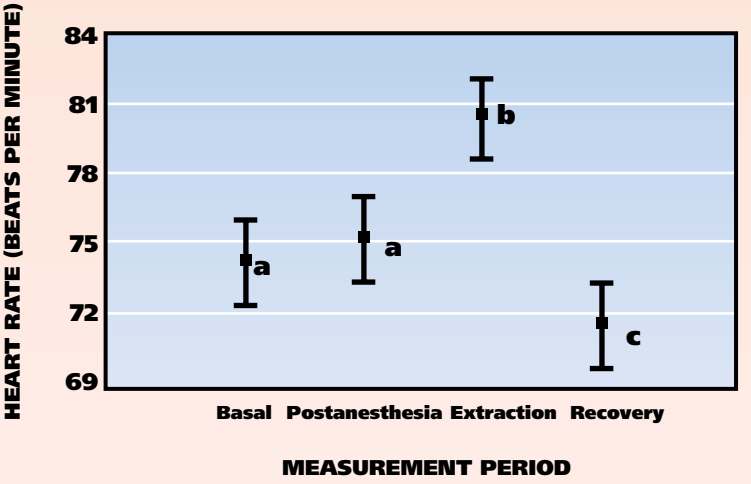

Figure 3. Time-dependent variation in heart rate (mean ± 95 percent least significant difference intervals) during dental extractions. Different letters indicate significant differences between periods. F = 18.8; *P* < .01.

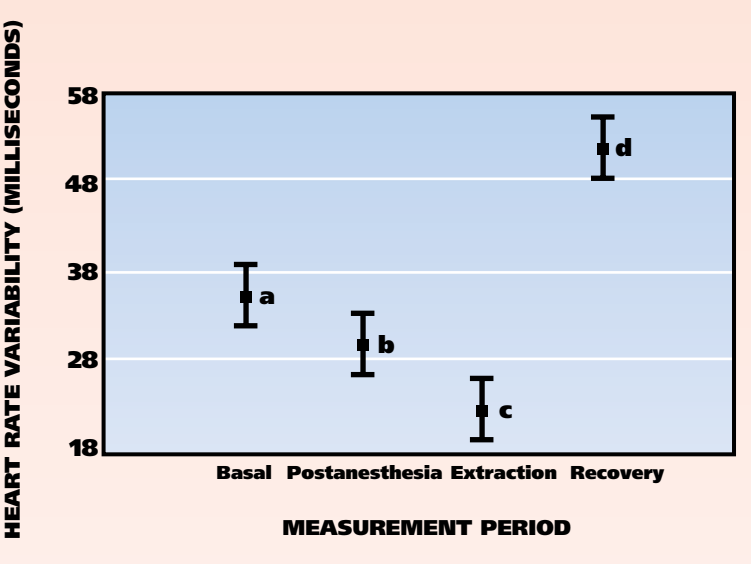

Figure 4. Time-dependent variation in heart rate variability (mean ± 95 percent least significant difference intervals) during dental extractions. Different letters indicate significant differences between periods. F = 40.7; *P* < .01.

Mean BP and HR values. Both SBP and DBP values were not influenced significantly by stress caused by the local anesthetic and dental extraction, or by relaxation during the recovery period. On the other hand, HR seemed to be much more sensitive than BP, being able to differen-

tiate mean values recorded during the extraction and recovery periods from those recorded at baseline, as well as after administration of the local anesthetic; however, there were no statistically significant differences between baseline values and values recorded immediately after administration of the anesthetic.

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Mean HRV values. The results show that HRV was the only index that statistically differentiated between all four testing periods; a wide range of HRV values was exhibited during the dental extraction, suggesting a higher sensitivity compared with that for BP and HR. Sensitivity reflects the ability of a measurement to provide information about the true value of the phenomenon being assessed.[22]

It is likely that cardiovascular reactions to stress differ among people, and we might be able to postulate that a wider range of values recorded during maximum stress can identify a more highly sensitive parameter. On this point, the range of HRV values among our subjects during the dental extraction was nearly twice the range of HR values recorded at the same time.

Heart rate variability was the only index that statistically differentiated between all four testing periods.

The results of our study suggest that HRV might be a valid marker for the early detection of high sympathetic nerve activity in subjects with heart disease. Within the last decade, HRV has become widely used in clinical practice and in clinical research, because it provides quantitative information about the modulation of cardiac vagal and sympathetic nerve activities. The autonomic nervous system plays a central role in the maintenance of hemodynamic stability, and HRV has been recognized as a powerful risk stratifier for adverse cardiac events. A depressed HRV indicates an increased risk of malignant dysrhythmias and death in patients with early myocardial infarction, as well as in patients with decompensated heart failure.[27-29]

Evidence indicates that mental stress, via an increase in sympathetic nerve activity, can induce ischemia in 30 to 60 percent of patients with coronary artery disease[30,31]; ischemia is the main cause of acute cardiac events because it causes a strong decrease in the left ventricular function or triggers lethal ventricular dysrhythmias.[32]

Researchers have demonstrated that patients with advanced heart failure have higher sympathetic nerve activity, even at rest, and, despite a blunted response during stress (consisting of very low BP and HR increases resulting from their cardiac impairment), they are at a high risk of reaching the maximal level beyond which a cardiac event is likely to happen.[1,2]

Future studies could include a time-course evaluation of HRV in patients with advanced heart disease who are undergoing an operative dental procedure. HRV could be useful in the early detection of abnormal increases in the sympathetic drive to the heart, and could provide the dentist with important information that would lead him or her to discontinue the procedure to avoid possible adverse cardiac events.

The apparently easy derivation of this measurement has popularized its use. Because many commercial devices now provide automated measurements of HRV, dentists have the opportunity to use a relatively simple tool (that involves the placement of electrodes only on patients' wrists) for both research and clinical studies. However, we must point out that this study was carried out in a population of healthy subjects, and future studies are needed to define precisely which patterns of HRV are associated with adverse cardiac events.

CONCLUSION

HRV is a highly sensitive parameter for quantifying the sympathetic drive to the heart during a cardiovascular reaction to a dental operation. The results of our study and other studies in the literature show that HRV differentiates well between various time periods in a dental extraction and highlights different cardiovascular reactions in

subjects with presumably different cardiovascular responses to dental stress.

HRV might be a useful parameter in detecting even small cardiocirculatory changes that other noninvasive tools might not be able to detect. For patients with heart disease who are undergoing operative dental procedures, HRV might be a useful monitoring tool to detect cardiac impairments related to local high sympathetic activity, as well as to prevent cardiovascular emergencies. ■

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