Evaluation of R-R interval variability with electromyography following coronary artery bypass grafting

Koroner arter bypass cerrahisi sonrasında R-R interval değişkenliğinin elektromiyografi ile değerlendirilmesi

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Background: Analysis of R-R interval variability (RRIV) provides information about cardiac autonomic function. Coronary artery bypass grafting (CABG) causes marked attenuation of RRIV. We analyzed RRIV with an alternative method using electromyography (EMG) in patients undergoing CABG.

Methods: The study included 19 consecutive patients (6 females, 13 males; mean age 57.8±10.2 years) undergoing CABG. R-R interval variability was assessed by EMG studies during quiet and deep breathing before, and one and two months after surgery.

Results: Compared to preoperative values, the mean RRIV values were significantly lower during quiet and deep breathing after one (R-R, quiet, p=0.001; R-R, deep, p=0.009) and two (R-R, quiet, p=0.001; R-R, deep, p=0.006) months of CABG. The mean RRIV values one month after surgery were significantly lower than those obtained two months postoperatively (R-R, quiet, p=0.01; R-R, deep, p=0.001). No correlations were found between RRIV and the following: age, gender, hypertension, smoking, total cholesterol, triglyceride, body mass index, duration of surgery, duration of cardiopulmonary bypass, cross clamp time, mechanical ventilation time, and intensive care unit stay.

Conclusion: Our data showed that CABG is associated with significant attenuation of RRIV within the first two postoperative months, with partial improvement in the latter. Analysis of RRIV with the use of EMG is an alternative method in patients undergoing CABG. It is not a time-consuming procedure, is easily performed in the EMG laboratory, and is a simple way of reflecting the autonomic function of the heart.

Key words: Arrhythmia; autonomic nervous system; coronary artery bypass; electrocardiography; electromyography; heart rate; neural conduction; postoperative complications; respiration.

Amaç: R-R interval değişkenliği (RRİD) analizi kalbin otonomik fonksiyonu hakkında bilgi verir. Koroner arter bypass cerrahisi sonrasında RRİD belirgin olarak azalmaktadır. Çalışmamızda, koroner arter bypass cerrahisi uygulanan hastalarda alternatif bir yöntem olarak elektromiyografi (EMG) ile RRİD değerlendirildi.

Çalışma planı: Çalışmaya koroner arter bypass cerrahisi yapılan 19 hasta (6 kadın, 13 erkek; ort. yaş 57.8±10.2) alındı. Tüm hastalarda istirahat ve hiperventilasyon sırasında olmak üzere, ameliyat öncesinde ve ameliyattan bir ve iki ay sonrasında EMG ile RRİD analizi yapıldı.

Bulgular: Ameliyat öncesiyle karşılaştırıldığında, ameliyattan bir ay (R-R, istirahat, p=0.001; R-R, hiperventilasyon, p=0.009) ve iki ay (R-R, istirahat, p=0.001; R-R, hiperventilasyon, p=0.006) sonra istirahat ve hiperventilasyon sırasında elde edilen ortalama RRİD değerleri anlamlı derecede düşük bulundu. Ameliyattan bir ay sonraki ortalama RRİD değerleri, ikinci ay sonundaki değerlerden anlamlı derecede düşük idi (R-R, istirahat, p=0.01; R-R, hiperventilasyon, p=0.001). R-R interval değişkenliği ile yaş, cinsiyet, hipertansiyon, sigara içme, total kolesterol ve trigliserid düzeyleri, beden kütle indeksi; cerrahi, kardiyopulmoner bypass, kros klemp, mekanik ventilasyon ve yoğun bakımda kalma süreleri arasında ilişki görülmedi.

Sonuç: Bulgularımız, koroner arter bypass ameliyatından sonraki ilk iki ayda RRİD değerlerinin anlamlı derecede düştüğünü, ikinci aydaki değerlerde kısmi düzelme meydana geldiğini gösterdi. R-R interval değişkenliğinin EMG ile analizi, koroner arter bypass ameliyatı uygulanan hastalarda zaman kaybına yol açmayan, EMG laboratuvarında kolaylıkla yapılabilen ve kalbin otonomik fonksiyonunu yansıtan bir seçenektir.

Anahtar sözcükler: Aritmi; otonomik sinir sistemi; koroner arter bypass; elektrokardiyografi; elektromiyografi; kalp hızı; nöral iletim; ameliyat sonrası komplikasyon; solunum.

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It has been reported that analysis of R-R interval variability (RRIV) can provide information about cardiac autonomic function.[1,2] Several studies showed a marked attenuation of RRIV following coronary artery bypass grafting (CABG).[3,4] It is important to determine whether RRIV can return to its presurgical level after CABG, because it has been reported that diminished RRIV is an independent predictor of mortality in patients with coronary artery disease.[5,6] In these studies, cardiac autonomic function and RRIV were assessed in CABG patients by electrocardiography or spectral analysis of heart rate. In our study, we analyzed RRIV with an alternative method using electromyography (EMG) before and after CABG.

PATIENTS AND METHODS

Patients. In this study, 19 consecutive patients (6 females, 13 males; mean age 57.8±10.2 years) scheduled for CABG were included. Exclusion criteria were atrial fibrillation, use of antiarrhythmic medications, diabetes mellitus, myocardial infarction within six weeks before surgery, use of inotropic drugs, and a reduced ejection fraction of less than 30%. Approval of the institutional review board was obtained, and all the patients gave their written informed consent.

Surgical management. In all cardiac procedures, central catheterization via the right internal jugular vein was performed. For premedication, morphine sulphate and scopolamine were injected intramuscularly. The patients were anesthetized with intravenous midazolam, etomidate, fentanyl citrate, and pancuronium and ventilated with oxygen in air. Ventilation was set to a tidal volume of 8 ml/kg and a respiratory rate of 12/min. In all the patients, a cardiopulmonary bypass circuit was initiated with a roller pump and a nonpulsatile flow technique with a membrane oxygenator. Initially, antegrade crystalloid cardioplegic solution (Plegisol, Abbott Laboratories, Chicago, IL, USA) at 4 °C was delivered into the aortic root at a dose of 10 ml/kg, followed by retrograde infusion of more cardioplegic solution at approximately 20-minute intervals. During the operation, moderate hypothermia (nasopharyngeal temperature 28 °C) and moderate hemodilution (hematocrit value 22% to 24%) were used. The pump rate was set at 2.4 $l.m^{-2}.min^{-1}$ and mean arterial pressures were kept between 60 and 80 mmHg. For topical hypothermia during cardiopulmonary bypass, the patients received around 250-300 ml ice-slush (lactated Ringer's) around the heart within the pericardium after completion of each distal anastomosis. For CABG, the left internal mammary artery was used in combination with saphenous grafts.

Measurement of R-R interval variability. R-R interval variability was assessed during quiet and deep breathing before, and one and two months after surgery. Before RRIV analysis, EMG studies were performed to assess motor and sensory conduction and patients who had polyneuropathy were excluded from the study. For the measurement of RRIV, two surface electrodes were placed on the chest, a ground electrode was placed around one wrist, and recording was made on a Medelec Synergy EMG machine. The patients were allowed to rest before the procedure. The first run was obtained during quiet breathing and the next during deep breathing. Sweep velocity was 100-200 msec/div, sensitivity was 200-500 micV/div, and the frequency band was 10-100 Hz. Using the triggering mode and delay line, the oscilloscope display was adjusted to the trigger sensitivity and sweep speed so that two QRS complexes could be displayed on the screen. Since the first QRS complex was the triggering potential, the variation in timing of the second QRS complex represented the variation in the R-R interval.

Twenty traces were recorded and superimposed. Five groups of 20 sweeps were recorded during quiet breathing, and two during forced deep breathing at 6 breaths/min. The RRIV was expressed as a percentage of the average R-R interval using the following formula: $(R\text{-}R_{max}\text{-}R\text{-}R_{min})$ x 100 / $R\text{-}R_{mean}$ (the difference between the shortest and the longest R-R intervals during 1 minute given in percent of all maximal and minimal peaks) (Fig. 1).[7]

Statistical analysis. Data were analyzed using the Minitab release 13 statistical program. Comparisons were made using the Friedman test and source of difference was investigated using a nonparametric test for two related samples (Wilcoxon signed rank test). The results were expressed as mean ± standard deviation. The level of significance was set at $p<0.05$.

RESULTS

Baseline characteristics of the patients and operative data are shown in Table 1 and 2, respectively.

The mean R-R interval variability values obtained during quiet and deep breathing one and two months

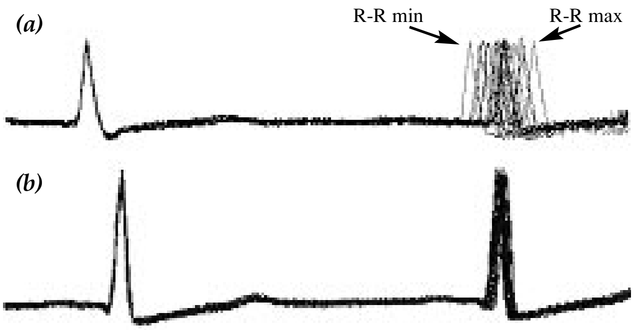

Fig. 1. R-R interval variability **(a)** in a healthy subject and **(b)** in a patient one month after coronary artery bypass grafting.

Table 1. Characteristics of the patients (n=19)

	Mean±SD	n	%
Mean age (years)	57.8±10.2		
Male	57.9±8.3		
Female	57.7±12.1		
Male/female		13	68.4
Female		6	31.6
Hypertension		15	79.0
Body mass index (kg/m^2)	26.5±3.4		
Cholesterol (mg/dl)	179.5±29.8		
Triglyceride (mg/dl)	149.9±71.4		
Smoking		12	63.2

Table 2. Operative data of the patients

Duration	Mean±SD
Duration of surgery (min)	283.4±25.6
Duration of cardiopulmonary bypass (min)	97±20
Cross clamp time (min)	53.1±12.8
Mechanical ventilation time (h)	15.8±4.9
Intensive care unit stay (h)	78.2±27.6

after CABG were found to be statistically lower than preoperative values. Of the two postoperative values, the letter RRIV was significantly higher than the former during both quiet and deep breathing (Table 3).

There was no correlation between RRIV and the following parameters: age, gender, hypertension, smoking, total cholesterol, triglyceride, body mass index, duration of surgery, duration of cardiopulmonary bypass, cross clamp time, mechanical ventilation time, and intensive care unit stay.

DISCUSSION

In this study, we assessed RRIV during quiet and deep breathing before and after 1 and 2 months of CABG. We used an alternative method that was demonstrated to be easy, reliable, and useful for the assessment of cardiac autonomic function in patients with neuromuscular conditions.[8] The RRIV values obtained during quiet and deep breathing were found to be significantly lower in the postoperative period compared to presurgical values. Moreover, at the end of the first postoperative month, RRIV values were significantly lower than those of the second month. Clinical and surgical features did not show any significant effect on the RRIV.

Heart rate is under the control of the vagus, and it increases during inspiration especially during hyperventilation.[9] Many factors influence fluctuations in heart rate during respiration. Neural coupling within the central nervous system causes channel overflow from the respiratory center to the medullary vagal efferent neurons, resulting in inhibition of vagal efferent activity on inspiration. Heart rate intervals fluctuate in response to the local intracardiac or sinus node stretch reflex.[10-12] During hyperventilation, R-R intervals may be influenced by the baroreflex as well as by the stretch reflex of pulmonary receptors or neural coupling within the central nervous system.[13] Cardiac interbeat interval dynamics can be assessed by RRIV, and it has been shown that measurement of RRIV during normal and deep breathing is an easy, reliable, and useful method for the assessment of parasympathetic cardiac function. If variations in R-R intervals are equal during hyperventilation, this means that the vagal control no longer exists.[8]

It has been shown that cardiac autonomic function may be severely influenced after CABG, which is associated with marked attenuation of RRIV.[4,14-17] Many factors have been suggested to be responsible for this attenuation. Storella et al.[18] determined RRIV before anesthesia, during anesthesia just before cardiac surgery, and on the first postoperative day in patients undergoing cardiac surgery and showed that RRIV decreased significantly with anesthesia. Other causes of attenuation of RRIV include perisurgical stress response such as pain, recent myocardial infarction, reduced left myocardial function, concomitant medications, and procedure-related causes such as inadequate myocardial protection during operation, direct mechanical injury to the vagus nerve or sinus node, or subclinical central nervous system involvement due to intraoperative microembolism.[3,4,19-22]

Diminished RRIV has been reported as a predictor of mortality in patients with coronary artery disease. It has also been reported that return of RRIV to presurgical levels after CABG has a great value for prognosis.[23,24]

In many studies, cardiac autonomic function was assessed with determination of RRIV by electrocardiography or by spectral analysis of heart rate during the perioperative period in CABG patients.[4,14,16,25] In these

Table 3. R-R interval variation values before, and after 1 and 2 months of coronary artery bypass grafting

	Preoperative[1] Mean ± SD	1 month after CABG[2] Mean ± SD	$p^{1,2}$	2 months after CABG[3] Mean ± SD	$p^{1,3}$	$p^{2,3}$
R-R, quiet breathing, %	10.4±3.7	5.3±4.1	0.001	7.3±3.6	0.009	0.01
R-R, deep breathing, %	15.1±4.7	7.3±4.1	0.001	11.1±3.6	0.006	0.001

studies, all the RRIV parameters showed a marked decrease in the early postoperative period, after which they mostly improved three months after CABG, with total improvement in the third postoperative year.[3,4,16] Kuo et al.[26] found significant attenuation of the RRIV parameters one month after CABG, which returned to preoperative levels within two months and remained there for the rest of the follow-up period. In our study, we found significant attenuation of RRIV at the end of the first month, with partial improvement in the second month. This partial improvement was consistent with most of the previous studies.[3,4,16] We did not evaluate RRIV in the early postoperative period, so we cannot comment on anesthesia-induced effects on RRIV. We did not find any correlation between RRIV and age, gender, hypertension, smoking, total cholesterol, triglyceride, body mass index, duration of surgery, duration of cardiopulmonary bypass, cross clamp time, mechanical ventilation time, and intensive care unit stay. Since anesthesia-induced effect and perioperative stress response did not exist beyond one month, significant attenuation of RRIV seen one month after CABG might have been due to procedure-related causes of CABG such as inadequate myocardial protection during operation or to direct mechanical injury to the vagus nerve or sinus node.[3,4,19,22,26]

Graft failure in the early period associated with myocardial ischemia following CABG may cause a decrease in RRIV such as that seen in acute myocardial infarction.[27-29] A postoperative control angiogram to detect early graft failure could not be possible in our patients. However, other findings suggesting early graft failure such as hemodynamic deterioration, ischemic chest pain, myocardial infarction, ischemic signs on electrocardiography, or increases in blood enzymes were not detected in the early postoperative period. Preoperative beta-blocking therapy was continued in the postoperative period. In addition, ACE inhibitors were discontinued in the preoperative period and were not administered postoperatively. Diverse dosages of ACE inhibitors were not found to exert different effects on RRIV in heart failure patients.[30,31] Several studies showed that beta-blocking agents, nitric oxide, amiodarone, and ACE inhibitors can affect the autonomic nervous system.[32-36] We feel that significant attenuation of the RRIV parameters cannot be attributed to the effect of beta-blocking agents because they were routinely used in our patients both preoperatively and postoperatively.

In conclusion, analysis of RRIV with the use of EMG is an alternative method in patients undergoing CABG. It is not a time-consuming procedure, is easily performed in the EMG laboratory, and is a simple way of reflecting the autonomic function of the heart.

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