Continuous measurement of heart rate variability following carbon dioxide pneumoperitoneum during nitrous oxide/sevoflurane anaesthesia

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Abstract

Background: Previous studies of autonomic nervous system activity through analysis of heart rate variability (HRV) have demonstrated increased sympathetic activity during positive-pressure pneumoperitoneum. We employed an online, continuous method for rapid HRV analysis (MemCalc™, Tarawa, Suwa Trust, Tokyo, Japan) to demonstrate rapid changes in autonomic nervous system during pneumoperitoneum for laparoscopy.

Method: The powers of low-frequency (LF) (0.04-0.15 Hz) and high-frequency (HF) (0.15-0.4 Hz) components of HRV in 20 healthy adult patients were monitored under sevoflurane anaesthesia for 10 minutes after the initiation of carbon dioxide pneumoperitoneum at 10 mmHg.

Results: Heart rate increased promptly, but transiently, just after peritoneal insufflation. At that time, the ratio between the LF and HF components increased on HRV. Similar, but small, changes occurred following head-up positioning.

Conclusion: By monitoring HRV continuously, we have demonstrated that the change in autonomic nervous system balance induced by peritoneal insufflation was prompt and transient. The change in autonomic nervous system activity could have been due to increased sympathetic activity, reduced vagal activity, or both.

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Introduction

Power spectral analysis of the electrocardiographic R-R interval [heart rate variability: (HRV)] is a well known, non-invasive method for assessing autonomic nervous activity.[1] Studies using HRV analysis during positive-pressure pneumoperitoneum (PPP) have demonstrated increased sympathetic nervous system activity.[2,3] Most techniques require offline analysis of several minutes of data, with the result that the time course of the effects of PPP on the autonomic nervous system may be missed, especially during the initial stages of peritoneal insufflation, when haemodynamic responses are quite complex (e.g. decreased venous return, increased systemic vascular resistance, and increased vagal tone). Recently, a technique for rapid, online HRV analysis has become available (MemCalc™, Tarawa, Suwa Trust, Tokyo, Japan). This technique employs a combination of the maximum entropy method for spectral analysis and a non-linear least squares method for fitting analysis,[4] and its usefulness during general anaesthesia has been reported.[5,6,7] In contrast to conventional methods such as autoregressive modelling and Fourier transform, which require a series of R-R intervals for longer than five minutes, this method makes it possible to estimate HRV continuously from a very short series of R-R intervals (about 30). The purpose of our study was to determine the time course of autonomic nervous system responses to peritoneal insufflation and subsequent head-up tilt prior to laparoscopy using the MemCalc™ method for continuous HRV analysis.

Method

Approval for the study was obtained from the local ethics committee for medical research. Twenty patients, classified as American Society of Anesthesiologists (ASA) physical status I, who were scheduled to undergo elective laparoscopic cholecystectomy, gave informed consent for general anaesthesia and electrocardiographic monitoring for HRV analysis. No patients received drugs that affected their heart rate and no premedication was administered. A continuous electrocardiographic signal was obtained from a conventional anaesthesia electrocardiogram (ECG) monitor, and was automatically downloaded to the MemCalc™ software. In real time, the software calculated and displayed the power of the low-frequency (LF) component (0.04-0.15 Hz) and the high-frequency (HF) component (0.15-0.4 Hz) of HRV, as well as the power ratio, LF/HF, every two seconds.

Anaesthesia was induced using intravenous injections of propofol (2 mg/kg) and fentanyl (2 μg/kg). Vecuronium

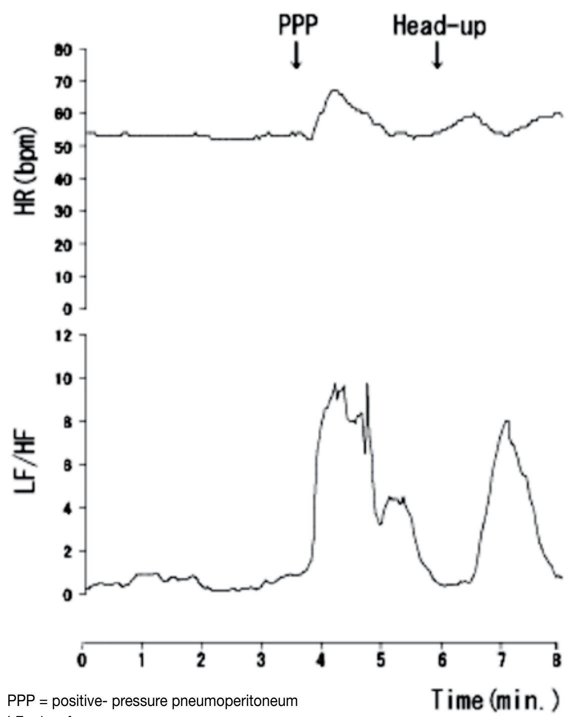
(0.15 mg/kg) was administered for muscle relaxation and subsequent tracheal intubation. Thereafter, anaesthesia was maintained using 60% nitrous oxide in oxygen and 1-2% sevoflurane. Ventilation was controlled mechanically by employing a tidal volume of 10 ml/kg at a frequency of 10-12/minute to maintain normocapnia (end-tidal carbon dioxide partial pressure: 35-40 mmHg). Pneumoperitoneum was induced by insufflation of carbon dioxide, and intra-abdominal pressure was maintained automatically at 10 mmHg. After insufflation, the patients were placed in a 10 degrees head-up position to facilitate surgery. Heart rate, LF, HF and LF/HF were monitored continuously in real time for 10 minutes after insufflation, and the data were automatically downloaded to the computer hard disk for further analysis.

Statistical analysis

We compared the values for heart rate and LF/HF obtained at the following stages: pre-anaesthesia, pre-insufflation, post-insufflation (30 seconds after insufflation), pre-head-up positioning, and post-head-up positioning (30 seconds after head-up positioning). As the data were not normally distributed, we employed Friedman's repeated measures analysis of variance on ranks and Scheffé's method for post hoc multiple comparisons at a significance level of 0.05 (Excel Tokei 2008 software, SSRI Co, Tokyo, Japan).

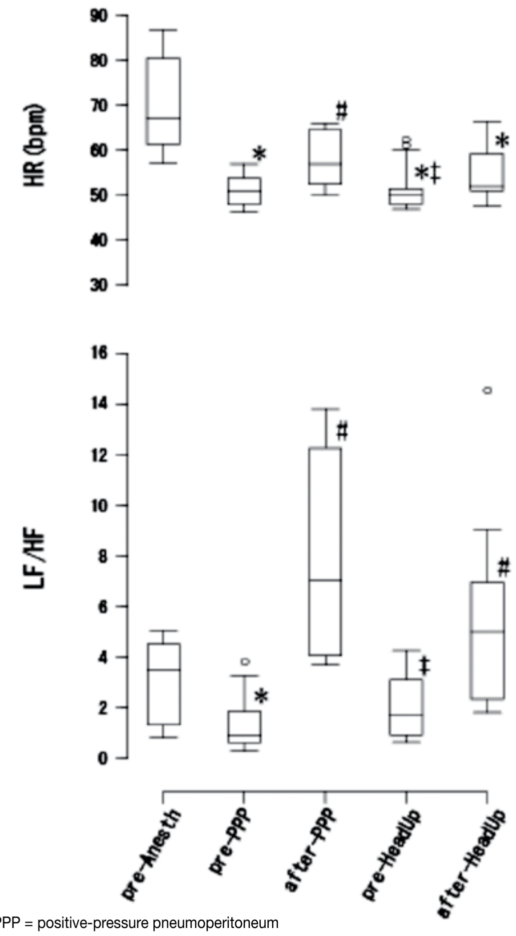
Results

One patient required treatment for bradycardia and hypotension before PPP, and was omitted from the study.



PPP = positive- pressure pneumoperitoneum
LF = low frequency
HF = high frequency
HR = heart reate

Figure 1: Representative traces of heart rate and the power of the low/high frequency ratio.



PPP = positive-pressure pneumoperitoneum
LF = low frequency
HF = high frequency
HR = heart reate
*= p-value < 0.05 versus pre-anaesthetic
= p-value < 0.05 versus pre-PPP
‡ = p-value < 0.05 versus after-PPP

Figure 2: Box plot showing distributions of heart rate and the power of the low/high frequency ratio. Boxes represent the interquartile range (lower edge: 25th percentile, upper edge: 75th percentile). The median is denoted as the line across the box. Upper and lower lines extend from the corresponding percentile to the highest and lowest values, excluding outliers (o).

Demographically, the remaining 19 patients were 55 ± 12 years old (mean ± standard deviation), male/female in a ratio of 6:13, with a height of 158 ±10 cm and a weight of 56 ± 9 kg. Figure 1 depicts the changes in HRV that occurred in a typical patient at each stage of the study, while Figure 2 shows the group changes. Soon after initiating PPP, the heart rates of the patients increased significantly, accompanied by increased LF/HF (p-value < 0.05). These changes were transient, with HRV returning to pre-PPP values within minutes. Following head-up positioning, there was a small, statistically significant increase in LF/HF.

Discussion

Autonomic nervous system activity during PPP has previously been studied using conventional methods, such as Fourier transform to analyse HRV, and these studies have shown that PPP leads to increased sympathetic cardiac activity.[2,3] However, these techniques require at least five-minute recordings of R-R intervals in order to calculate HRV variations.[8] In this study, we recorded HRV continuously during PPP using a recently introduced method (MemCalc™),[4] and demonstrated that the change in sympathovagal balance was prompt and transient, and was accompanied by increased heart rates.

HRV is a well-established, noninvasive method for assessing autonomic nervous activity[1] that enables assessment of the balance between the sympathetic and parasympathetic nervous systems. The efferent vagal activity is a major contributor to the HF component, as has been seen in clinical and experimental observations of autonomic manoeuvres, such as electrical vagal stimulation, muscarinic receptor blockade and vagotomy.[8] However, under certain conditions, such as general anaesthesia,[9] changes in HF are not always associated with changes in vagal activity, and the normalisation of HF does not necessarily reflect changes in vagal activity.[10] Controversy exists with regard to the LF component.[8] Some studies suggest that LF is a quantitative marker of sympathetic modulations when expressed in normalised units,[11,12] while other studies suggest that LF is a reflection of both sympathetic activity and vagal activity.[1,13] LF/HF is also considered to mirror sympathovagal balance, or to reflect the sympathetic modulations.[14] In our study, we adopted LF/HF as an indicator of sympathovagal balance.

The MemCalc™ method, a combination of the maximum entropy method for spectral analysis and a non-linear least squares method for fitting analysis,[4] has recently been introduced during general anaesthesia.[5,6,7] In contrast to conventional methods, such as autoregressive modelling and Fourier transform, which require R-R intervals longer than five minutes, this method is able to estimate HRV continuously and almost in real time (the data are renewed every two seconds) from a small series of R-R intervals. This enables the capturing of short-term changes in HRV. Using this method, we found that, after peritoneal insufflation, the increase in LF/HF was prompt and transient. It resulted in the detection of changes that could not have been determined using conventional methods. It appears that, by themselves, PPP and head-up tilt do not result in prolonged changes in sympathovagal balance in healthy adult patients, although further studies are needed on patients with hypertension or diabetes, which are conditions that affect the sympathetic nervous system.[15]

Conclusion

In conclusion, the findings of our study are in accordance with those of studies that used measurements of HRV,[2,3] namely that PPP and head-up tilt result in changes in sympathovagal balance that can possibly be interpreted as increased sympathetic activity, decreased vagal activity, or both. In the light of the findings of previous reports,[2,3] it is likely that these changes occurred mainly as a result of increased sympathetic activity. In addition, we are the first to report that after peritoneal insufflation, increased LF/HF was prompt and transient.

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