原 著

Preoperative non-invasive assessment of stress response to breath-holding test

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Abstract

The purpose of this study was to evaluate circulatory and respiratory responses to a breath-holding stress test in surgical patients at the bed-side using continuous and non-invasive monitoring with arterial tonometry and pulse oxymetry. Sixty-one patients were assigned into four groups: normal healthy patients (Cont), elderly patients (Elder), hypertensive patients (HT) and diabetic patients (DM). The breath-holding stress test was conducted in the supine position at the functional residual capacity level and in room air. Breath-holding time, changes in heart rate (HR), mean arterial pressure (MAP), arterial oxyhemoglobin saturation using a pulse oxymeter (SpO_2) and the recovery time of SpO_2 were measured. Breath-holding time was significantly shorter in the HT group (30±2.0sec, $p < 0.05$) and tended to be shorter in the Elder group (31±3.0sec, $p = 0.08$) compared with the Cont group (41±2.9sec). The maximum mean arterial blood pressure (Max-MAP) was higher in the Elder (105±4.0mmHg) ($p < 0.05$) and HT (128±5.6mmHg) ($p < 0.05$) groups compared with the Cont group (93±4.0mmHg). However, ⊿MAP, ⊿HR, Min-SpO_2, and ⊿SpO_2 were not significantly different among the four groups. Our results suggest that non-invasive continuous monitoring facilitates evaluation of stress responses to breath-holding in preoperative patients, and that the breath-holding stress test causes sympathetic augmentation, resulting in increases in MAP and HR by approximately 15%, concomitant with a decrease in SpO_2 to 90–94%. The magnitude of the response is similar regardless of age and existence of HT and DM.

Key words; Breath-holding, stress test, homodynamic, preoperative, tonometry

Introduction

Preoperative evaluation of a patient is one of the most important roles of anesthesiologists, especially given the recent clinical tendency for increased proportion of geriatric surgical patients. The breath-holding stress test is a simple stress test available to anesthesiologists and can be conducted during the preoperative visit. However, the magnitude and time-course of stress responses to the breath-holding stress test remain unclear. The purpose of this study was to evaluate circulatory and respiratory responses to the breath-holding stress test in patients using continuous and non-invasive monitoring and to compare the responses among normal healthy, elderly, hypertensive, and diabetic patients.

Materials and Methods

Surgical patients were studied after obtaining ethical approval for the project from our institution and informed consent from patients. Sixty-one patients

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were enrolled in the study. Patients were assigned into four groups: normal healthy patients (Cont) aged <65 years (n=13, mean age: 36 years, range: 22-64 years), elderly patients (Elder) aged >65 years with no cardiac complications or hypertension (n = 19, mean age: 73 years, range: 65-84 years), hypertensive patients (HT) with a history of HT and currently receiving antihypertensive therapy (n=21), and diabetic patients (DM) receiving insulin therapy (n=8). The breath-holding stress test was conducted at the bed-side in the supine position, and at the end of passive exhalation, namely, at the functional residual capacity (FRC) level and while breathing room air without hyperventilation. Stress responses to the breath-holding stress test were assessed by continuous measurement of oxyhemoglobin saturation using a pulse oximeter (SpO_2), recording of electrocardiogram, continuous monitoring of arterial blood pressure using arterial tonometry, and heart rate (BP508, Nihon Colin Electronics, Komaki, Japan). Breath-holding time, changes in heart rate (HR), arterial pressure, SpO_2 and the recovery time of SpO_2 were measured. All data were expressed as mean±SEM (standard error of the mean). Differences between groups were examined for statistical significance using the Student's *t*-test and one-factor ANOVA with Posthoc test (Games Hwell). A *p* value less than 0.05 denoted the presence of a statistically significant difference.

Results

Patient demographic data are shown in **Table 1**. The mean ages of the Cont, Elder, HT and DM groups were 28, 74, 66, and 67 years, respectively. The mean arterial pressure (MAP) in the HT group was significantly higher than in the Cont group.

Typical recordings of changes in MAP, HR and SpO_2 during the breath holding test are shown in **Fig. 1**. In this 35-year-old female, the breath-holding time was 42 sec. SpO_2 gradually decreased and reached a minimum value of 88% at 15sec, and thereafter recovered to the pre-breath-holding level at approximately 40sec after cessation of breath-holding. Her MAP and HR increased and reached the maximum changes of 20mmHg and 25 beats/min, respectively, at the end of breath-holding.

Table 1 Patient demographics

	Cont	Elder	HT	DM
n	13	19	21	8
Age (yr)	28±1	74±1*	66±2*	67±4*
Height (cm)	166±3	159±3	154±2*	157±4
Weight (kg)	63±3	57±2	56±2	55±2

Data are mean±SEM.
Cont: control group, Elder: elderly group, HT: hypertensive group, DM: diabetic group.
*p<0.05 compared with Cont.

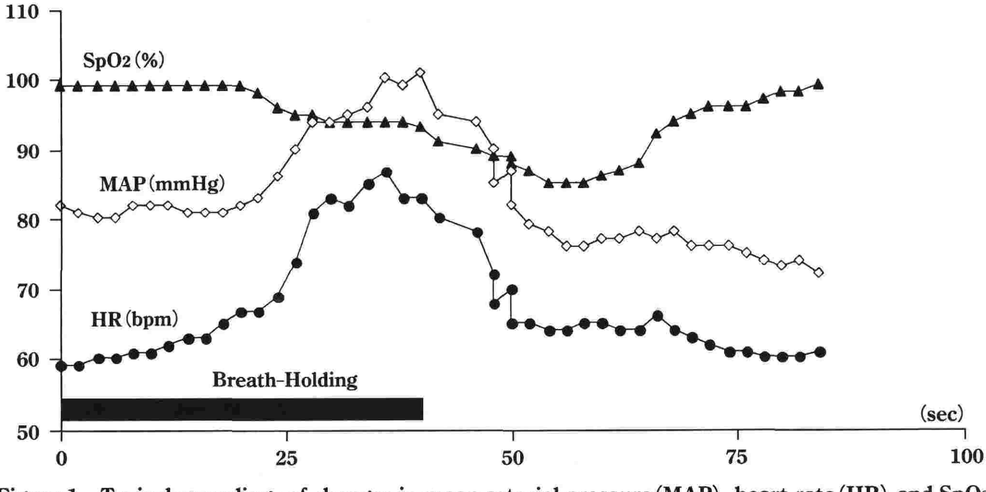

Figure 1 Typical recordings of changes in mean arterial pressure (MAP), heart rate (HR) and SpO_2. See **Results.**

Table 2 Changes in MAP, HR and SpO_2 during breath-holding test conducted at end expiration during room air breathing

	Cont	Elder	HT	DM
Breath-holding time (sec)	41±3	31±3	30±2*	42±2
Baseline MAP (mmHg)	78±3	89±3	113±5*	87±6
Max-MAP (mmHg)	93±4	105±4*	128±6*	100±7
⊿MAP (mmHg)	16±2	16±2	15±2	13±2
Baseline HR (bpm)	68±4	62±2	74±2	67±5
Max-HR (bpm)	76±3	69±2	81±3	74±7
⊿HR (bpm)	8±11	7±9	8±5	7±9
Baseline SpO_2 (%)	98±0.4	98±0.3	97±0.3	98±0.5
Min SpO_2 (%)	92±3.6	94±4.4	92±4.6	90±5.7
⊿SpO_2 (%)	6.6±4.3	3.8±3.5	4.8±2.7	7.5±4.2
Recovery time (sec)	35±3	33±2	26±2*	37±3

Data are mean±SEM.
MAP: mean arterial blood pressure, HR: heart rate, SpO_2: oxyhemoglobin saturation.
For other abbreviations, see **Table 1**.
*$p<0.05$ compared with Cont.

Changes in MAP, HR and SpO_2 of the four groups are shown in **Table 2**. Breath-holding time was significantly shorter in the HT group (30±2.0sec) ($p<0.05$) and tended to be shorter (albeit insignificantly) in the Elder group (31±3.0sec) ($p=0.08$) than in the Cont group (41±2.9sec). The recovery time was significantly shorter in HT group than in Cont group. Maximum MAP (Max-MAP) was significantly higher in the Elder (105±4.0mmHg) ($p<0.05$) and HT (128±5.6mmHg) ($p<0.05$) groups than in the Cont group (93±4.0mmHg). However, ⊿MAP, ⊿HR, Min-SpO_2, and ⊿SpO_2, were not significantly different among the four groups.

Discussion

Preoperative evaluation of surgical patients is mandatory for optimal anesthetic management. Several stress tests have been used in preoperative evaluation. The breath-holding stress test is a simple stress test available to anesthesiologists during their preoperative visit that does not require any invasive monitoring. Current non-invasive continuous monitoring devices, such as arterial tonometry and pulse oximetry, have facilitated evaluation of circulatory and respiratory stress responses to breath-holding. Our present study has demonstrated that breath-holding time was around 30 to 40sec and SpO_2 continued to decrease and reached a nadir at 10 to 20sec after the cessation of breath-holding, in association with maximal increases in blood pressure and heart rate by approximately 15%, which were elicited at the end of breath-holding.

Breath-holding time depends on lung volume and PO_2 of inspired gas[1,2] and it is significantly limited by an increase in $PaCO_2$[2]. It has been shown that breath-holding time is approximately 1min at room air, when PaO_2 decreases to approximately 65-70mmHg and $PaCO_2$ increases by approximately 12mmHg. The rate of the increase in $PaCO_2$ has been shown to be 43mmHg/min during the first 10sec, 13mmHg/min during the next 10sec, and 6mmHg/min thereafter[2]. The endpoint of breath-holding time has been reported to correspond to a $PaCO_2$ of approximately 50mmHg[2,3]. Hyperventilation before breath-holding, therefore, can prolong the breath-holding time to 3-4 min[1].

Sasse, et al[4] has reported, using an invasive arterial blood gas analysis, that breath-holding time at FRC is about 35sec and the arterial $PaCO_2$ increases by 10.2mmHg at the end of breath-holding. Their reported breath-holding time is similar to that of our normal healthy patients (40±2.0sec). Stock, et al[2] also reported that $PaCO_2$ is about 50mmHg after 40sec of apnea at FRC. Therefore, the $PaCO_2$ of our patients may also be expected to have reached ~ 50mmHg at the end of breath-holding.

The FRC has been shown to increase with aging due to expansion of alveolar spaces and emphysematous lung[5,6], which can prolong the duration of breath-holding. On the other hand, in elderly patients with emphysematous lung, the baseline $PaCO_2$ may be higher than normal. In addition, elderly patients cannot tolerate the dyspneic sensation as compared with normal subjects, resulting in a decrease in breath-holding time. The result of these complex factors is that the breath-holding time of elderly (Elder) patients tended to be shorter ($p<0.08$) than that of normal healthy (Cont) patients in this study.

The breath-holding time in hypertensive patients was significantly shorter than in normal healthy patients, and was similar to that in elderly patients. The age of the hypertensive patients was also similar to that of the elderly patients, which may have contributed to the shorter breath-holding time in hypertensive patients compared with normal healthy patients. The breath-holding stress test has been performed previously in hypertensive patients to evaluate responses of blood pressure to stimuli[7,8], where the systolic blood pressure increased by 12% in normal subjects and by 30-40% in hypertensive subjects after 20sec of apnea. In our study, the increase of mean arterial blood pressure was about 15% in all groups. This only slight increase in blood pressure may be attributed to the use of antihypertensive drugs in our hypertensive patients.

In diabetic patients, the responses to breath-holding were similar to those in normal healthy patients. Since our diabetic patients had received insulin therapy and were not complicated by autonomic neuropathy, the hemodynamic responses appeared to be similar to those in other groups. If diabetic patients also had autonomic neuropathy, the responses obtained may differ. Several cardiovascular tests have been performed to evaluate autonomic neuropathy in diabetic patients, including heart rate variation in response to deep breathing, standing and the Valsalva maneuver, and also the recording of postural change in systolic blood pressure. The breath-holding test may therefore become a suitable alternative to these cardiovascular tests.

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