Comparative Study on the Cardio-respiratory Change during Prostaglandin E_1-induced Hypotension in the Patients in the Supine and Prone Position

Munetaka HIROSE, Kengo YODA*, Kazuo SAKAI*,
Akiko SAITOH*, Hiromi NAKAGAWA, Masaki TANAKA
and Masao MIYAZAKI**

Prostaglandin E_1-induced hypotension (25% reduction from the preadministration level in mean arterial pressure) was applied to thirteen patients. Eight patients among them were operated in the supine position (group I) and other five in the prone position (group II). The maintenance dose of PGE_1 was considerably lower in group II than in group I (0.067 $\mu g \cdot kg^{-1} \cdot min^{-1}$ vs. 0.119 $\mu g \cdot kg^{-1} \cdot min^{-1}$). In group I, there was a significant increase in CI, with a significant decrease in SVRI and PVRI during PGE_1-induced hypotension. Such a high dose of PGE_1 (0.119 $\mu g \cdot kg^{-1} \cdot min^{-1}$) was considered to have a direct dilating action on the systemic resistance bed as well as on the pulmonary vasculature. It was considered that the suppression of hypoxic pulmonary vasoconstriction could be a mechanism to increase venous admixture during PGE_1-induced hypotension. In group II, there was no significant increase in CI, and no significant decrease in SVRI and PVRI. PGE_1-induced hypotension can be safely applied to the anesthetized patients, but we should be careful to apply it to the patients in the prone position, because lower dose of PGE_1 can induce severe hypotension, which is not accompanied by the increase in CI as occures in the patients in the supine position. (Key words: hypotensive anesthesia, prostaglandin E_1, prone position)

(Hirose M, Yoda K, Sakai K, et al.: Comparative Study on the cardio-respiratory change during prostaglandin E_1-induced hypotention in the patients in the supine and prone position. J Anesth 5: 30–35, 1991)

Prostaglandin E_1 (PGE_1) is reported to have a vasodilating effect mainly on the resistance bed rather than on the capacitance bed. It is an agent which is used for vasodilator therapy and induced hypotension in clinical anesthesia. Several studies have been reported about PGE_1's cardiovascular[1–4] and respiratory effects[2,5,6] in the patients in the supine position, but not in the prone position. In this study the effects of PGE_1 on hemodynamics, blood gases and pulmonary gas exchange were investigated in the two groups of anesthetized patients, first group in the supine position and second group in the prone position.

Department of Anesthesia, Kyoto Prefectural University of Medicine, Kyoto, Japan

**Department of Anesthesia, Kyoto First Red Cross Hospital, Kyoto, Japan*

***Maizuru National Hospital, Kyoto, Japan*

Address reprint requests to Dr. Hirose: Department of Anesthesia, Kyoto Prefectural University of Medicine, 465 Kajiicho Hirokoji-dori Kawaramachi Kamigyoku Kyoto, 602 Japan

Table 1. Age, sex, position, FI_{O_2} and operation of the patients

Patient	Age/Sex	Position	FI_{O_2}	Operation
1	75/M	Supine	0.5	Abdominal Aortic Reconstruction
2	55/M	Supine	0.5	Aortoiliac Bypass
3	62/F	Supine	0.5	Clipping of Cerebral Aneurysm
4	51/F	Supine	0.5	Resection of Femoral Osteosarcoma
5	58/M	Supine	0.5	Cholecystectomy
6	54/F	Supine	0.5	Extirpation of Intracerebral Hematoma
7	60/M	Supine	0.5	Cervical Anterior Fusion
8	66/M	Supine	0.5	Esophagogastrostomy
9	67/M	Prone	0.5	Lumbar curettage
10	79/M	Prone	0.5	Lumbar Laminectomy
11	72/M	Prone	0.33	Thoracic Laminectomy
12	64/F	Prone	0.5	Cervical Laminectomy
13	55/M	Prone	0.5	Lumbar Posterior Fusion

Methods

The hypotensive technique with continuous intravenous infusion of PGE_1 was applied to thirteen patients, whose clinical characteristics are shown in table 1. Eleven patients among 13 had no cardiac abnormality. One patient with mitral stenosis, and the other with a history of old myocardial infarction, were included in this study, and both of them were in class I as classified by New York Heart Association. Informed consent was obtained from all patients.

Thirteen patients were divided into two groups; group I, consisted of 5 male and 3 female patients, was placed in the supine position during surgery, and group II, consisted of 4 male and 1 female patients, was studied in the supine position at first, then turned to the prone position.

As preanesthetic medication, all patients were given bromazepam 3 mg rectally 2 hr befofe the induction of anesthesia, and atropine sulfate 0.3–0.5 mg intramusculary 30 min before the induction of anesthesia. Anesthesia was induced with 4 $mg \cdot kg^{-1}$ of thiopental intravenously followed by 1–1.5 $mg \cdot kg^{-1}$ of succinylcholine chloride or 0.15 $mg \cdot kg^{-1}$ of vecuronium bromide. After endotracheal intubation, anesthesia was maintained with enflurane, fentanyl and 50% or 67% nitrous oxide in oxygen. Pancuronium bromide or vecuronium bromide was administered whenever it was required. The controlled ventilation was maintained to keep Pa_{CO_2} 30–40 mmHg during study. No positive end-expiratory pressure was applied. The radial artery was canulated for the direct blood pressure recording, and for sampling of arterial blood. No. 7 French size baloon-tipped, thermodilusion Swan-Ganz catherter was inserted into the pulmonary artery through the median basilic vein or the right internal juglar vein for measurement of right atrial pressure (RAP), mean pulmonary artery pressure (MPAP), pulmonary capillary wedge pressure (PCWP) and cardiac output (CO) and for sampling of mixed venous blood. After the patients were allowed to stabilize their condition, in group I, the first measurement was taken in the supine position and the second during PGE_1 infusion. In group II, the first measurement was taken in the supine position, the second in the prone position and the third during PGE_1 infusion in the prone position. The initial administration rate of PGE_1 was 0.1 $\mu g \cdot kg^{-1} \cdot min^{-1}$, then the dose was adjusted to maintain mean arterial pressure (MAP) at 75% of the preadministration level.

The measurement of blood gases, hemoglobin (Hb) saturation and Hb concentration of arterial and mixed venous blood was done with ABL 300 (Radiometer Co.). Cardiac output (CO) was measured with car-

Table 2. Hemodynamic changes in associated with PGE_1 during supine position

	HR (beats·min^{-1})	MAP (mmHg)	MPAP (mmHg)	PCWP (mmHg)	RAP (mmHg)	CI (l·min^{-1}·m^{-2})	SVRI (dyn·s·cm^{-5}·m^2)	PVRI (dyn·s·cm^{-5}·m^2)
Supine	79±2	108±5	16.1±1.2	9.6±1.6	6.7±1.3	2.55±0.32	3528±395	216±26
Supine with PGE_1	82±4	83±5*	11.7±0.9*	5.4±1.0*	4.5±1.1*	3.20±0.27*	2176±215*	164±20*

Values represent mean ± SE. HR, Heart rate; MAP, Mean arterial pressure; MPAP, Mean pulmonary aterial pressure; PCWP, Pulmonary capillary wedge pressure; RAP, Right atrial pressure; CI, Cardiac index; SVRI, Systemic vascular resistance index; PVRI, Pulmonary vascular resistance index.

*$P < 0.05$, vs. control value.

Table 3. Blood gases, venous admixture and oxygen consumption changes in associated with PGE_1 during supine position

	Pa_{O_2}/FI_{O_2} (mmHg)	$P\bar{v}_{O_2}$ (mmHg)	$\dot{Q}va/\dot{Q}t$ (%)	$\dot{V}o_2$ (ml·min^{-1}·m^{-2})
Supine	408.5 ± 30.7	43.1 ± 2.0	13.8 ± 1.3	120.7 ± 11.1
Supine with PGE_1	338.8 ± 35.9*	48.8 ± 2.0*	18.6 ± 2.6*	135.6 ± 8.2

Values represent mean ± SE. Pa_{O_2}/FI_{O_2}, Arterial oxygen tension/Fractional concentration of oxygen in inspired gas; $P\bar{v}_{O_2}$, Mixed venous oxygen tension; $\dot{Q}va/\dot{Q}t$, Venous admixture; $\dot{V}o_2$, Oxygen consumption.

*$P < 0.05$, vs. control value.

diac output computer model 9530 (Mansfield Scientific, Inc.). Venous admixture ($\dot{Q}va/\dot{Q}t$) was calculated by the following equation.

$$\dot{Q}va/\dot{Q}t=(C\bar{c}_{o2}-Ca_{o2})/(C\bar{c}_{o2}-C\bar{v}_{o2})$$

$C\bar{c}_{o2}$: pulmonary end-capillary blood oxygen content,

Ca_{o2}: arterial blood oxygen content,

$C\bar{v}_{o2}$: mixed venous blood oxygen content.

Oxygen consumption ($\dot{V}o_2$) was calculated by the following equation.

$$\dot{V}o_2 = CI \times (Ca_{o2} - C\bar{v}_{o2}) \times 10$$

CI: cardiac index.

All values are shown as mean ± standard error. One-way ANOVA was used for statistical evaluation and Student t-test was used to determine the statistical significance. $P < 0.05$ was taken as a statistically significant difference.

Results

In the patients in group I, 25% reduction in MAP was accompanied by a significant decrease in RAP, MPAP and PCWP, and a significant increase in CI. Heart rate (HR) showed no significant increase. Systemic vascular resistance index (SVRI) and pulmonary vascular resistance index (PVRI) decreased (table 2). There was a significant decrease in Pa_{O_2}/FI_{O_2} and a significant increase in both $\dot{Q}va/\dot{Q}t$ and $P\bar{v}_{O_2}$. $\dot{V}o_2$ did not change significantly (table 3).

In the patients in group II, there was no significant difference in all the parameters, when they were turned to the prone position, and even when PGE_1 was administered in this position (table 4 and 5). A mentionable phenomenon during this study was that the average dose of PGE_1 required to reduce MAP to 75% of control level in group II, was significantly lower (0.067 ± 0.017 $\mu g \cdot kg^{-1} \cdot min^{-1}$) than that required for group I (0.119 ± 0.018 $\mu g \cdot kg^{-1} \cdot min^{-1}$).

Discussion

In this study, we induced 25% reduction

Table 4. Hemodynamic changes in associated with PGE_1 during prone position

	HR (beats·min^{-1})	MAP (mmHg)	MPAP (mmHg)	PCWP (mmHg)	RAP (mmHg)	CI (l·min^{-1}·m^{-2})	SVRI (dyn·s·cm^{-5}·m^2)	PVRI (dyn·s·cm^{-5}·m^2)
Supine	65±3	82±6	15.8±1.0	9.8±0.7	5.0±0.9	2.33±0.18	2694±257	209±14
Prone	63±4	87±8	13.2±0.8	8.0±1.3	4.4±1.2	2.10±0.23	3343±487	221±52
Prone with PGE_1	68±5	68±3*+	12.4±1.3	6.4±1.5	4.0±1.6	2.60±0.39	2279±401	202±41

Values represent mean ± SE. $*P < 0.05$, vs. control value. $^+P < 0.05$, vs. prone value.

Table 5. Blood gases, venous admixture and oxygen consumption changes in associated with PGE_1 during prone position

	Pa_{O_2}/FI_{O_2} (mmHg)	$P\bar{v}_{O_2}$ (mmHg)	$\dot{Q}va/\dot{Q}t$ (%)	$\dot{V}o_2$ (ml·min^{-1}·m^{-2})
Supine	484.6 ± 67.3	39.4 ± 5.1	7.44 ± 1.4	127.0 ± 32.1
Prone	559.2 ± 42.0	40.5 ± 3.1	4.9 ± 1.1	124.3 ± 16.5
Prone with PGE_1	509.2 ± 45.6	45.1 ± 3.0	8.1 ± 1.7	132.7 ± 18.4

Values represent mean ± SE.

in MAP with PGE_1 infusion. In the patients in group I, who were placed in the supine position, the left ventricular (LV) preload and afterload decreased considerably, and CI increased during PGE_1-induced hypotension. On the other hand, in the patients in group II, who were placed in the prone position, 25% reduction in MAP was accompanied by no change in the LV preload and afterload and no significant increase in CI.

According to the study reported by Awan et al.[3], in which PGE_1 (mean dose of 0.03 $\mu g \cdot kg^{-1} \cdot min^{-1}$) was given to nine chronic coronary heart disease patients with severe LV dysfunction, PGE_1 did not alter HR and produced modest decline in MAP and LV filling pressure. PGE_1 also augumented LV pump function raising CI and decreased SVR. Concomitantly, in the forearm, vascular resistance fell, blood flow rose, and venous tone remained unchanged. They suggested that the mechanism of these advantageous improvement in cardiac function was probably related to the vascular relaxing action of PGE_1 on the systemic arteriolar resistance bed, thereby decreasing LV output impedance, facilitating cardiac emptying, elevating ejection fraction, and raising CI. It was also suggested that the enhancement in cardiac contractility was less likely mechanism for the augumentation of ventricular pump function. Popat et al.[4] reported that PGE_1 (mean dose of 0.0146 $\mu g \cdot kg^{-1} \cdot min^{-1}$), which was administered to five patients with acute myocardial infarction of less than 12 hr duration and LV dysfunction, produced a significant decrease not only in SVR but also in PVR. In our patients in group I, an average dose of 0.119 $\mu g \cdot kg^{-1} \cdot min^{-1}$ of PGE_1 was administered to induce hypotension, which was much more higher than that used in the forementioned studies. It was considered that a high dose of PGE_1 could have a direct dilating action on the pulmonary vasculature.

During PGE_1-induced hypotention, there was a significant increase in CI and $P\bar{v}_{O_2}$, and significant decrease in MPAP in group I. These changes could affect gas exchange since $\dot{V}o_2$ remained unchanged[7-9]. In this study, a significant decrease in Pa_{O_2}/FI_{O_2} and a significant increase in $\dot{Q}va/\dot{Q}t$ was found. This apparent decrease in the efficiency of gas exchange in the lung was

probably resulted from the change in the distribution of pulmonary blood flow, possibly due to the dilatation of vessels constricted in response to hypoxia, in other words, the suppresion of hypoxic pulmonary vasoconstriction (HPV) and also due to the decrease of MPAP and the increase of CI. The similar phenomenon is also reported during nitroprusside- and nitroglycerin-induced hypotension[9].

It is known that 23% of the patients who have myocardial ischemia has anatomic requirements to cause coronary steal[10]. The arteriolar type dilator like PGE_1, may produce coronary steal[11], when administered to the patients with coronary artery disease. Thus, PGE_1-induced hypotension should be applied carefully in the patients with coronary artery disease as quite a large number of such patients possess "steal-prone coronary artery".

It has been reported that the subjects placed in the prone position possessed a higher pressure in the inferior vena cava probably due to the increased impedance to the venous return. In this study, Hall-Frame was used to keep the patients in the prone position[12,13]. The frame is composed of two of paired pads, one pair of pads supports the upper thorax and the other supports the pelvis, causing minimum compression on inferior vena cava. Thus, the patients in the Hall-Frame position have shown no significant hemodynamic change. Moreover, considerably lower dose of PGE_1 (0.067 $\mu g \cdot kg^{-1} \cdot min^{-1}$ vs. 0.119 $\mu g \cdot kg^{-1} \cdot min^{-1}$ was required to induce 25% reduction in MAP in the patients in the prone position compaired with those in the supine position. This indicates that the greater degree of reduction in arterial pressure could be produced with an equivalent blood loss in the patients in the prone position than in the supine position.

In conclusion, PGE_1-induced hypotension (25% reduction from the control level in MAP) can be safely applied to the anesthetized patients, but we should be cautious when applying it to the patients placed in the prone position, because rather lower dose of PGE_1 can induce severe hypotension, which is not accompanied by the increased CI as occures in the patients in the supine position. The exact mechanism operating behind such a diversity remains to be clarified.

(Received Feb. 14, 1990, accepted for publication Jul. 20, 1990)

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