Changes in the hemodynamic parameters between the prone and supine positions measured by an arterial pulse contour cardiac output monitoring system

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Background: The changes in the hemodynamic parameters when the patients assumed a prone position from a supine position were examined using the FloTrac/EV1000™ system, during general anesthesia.

Methods: A total of 56 adult patients with American Society of Anesthesiologists physical status I-II and undergoing elective lumbar spine surgery were enrolled in the study. The hemodynamic parameters, such as the mean arterial pressure, heart rate, cardiac index, stroke volume variation, systemic vascular resistance index, central venous pressure, and peak airway pressure, were recorded when the patients were in a supine position and then in a prone position.

Results: No significant differences were found in the subjects’ hemodynamic parameters between when the subjects were in a supine position and when they were in a prone position, except in the central venous pressure and peak airway pressure, both of which were elevated when the subjects were in a prone position.

Conclusions: There were no differences in hemodynamic parameters between supine and prone positions measured by FloTrac/EV1000™ system during general anesthesia. (Anesth Pain Med 2015; 10: 291-294)

Key Words: EV1000™ clinical platform, FloTrac™, Hemodynamics, Prone position.

INTRODUCTION

Patients are commonly placed in a prone position for lumbar spinal surgery. Some studies reported that the mean arterial pressure (MAP) decreases and the heart rate (HR) increases when patients assume a prone position from a supine position [1]. Others reported, however, that the HR decreases and the MAP increases in the prone position [2].

There have not been many reports on the stroke volume variation (SVV) and the systemic vascular resistance index (SVRI) in relation to position change [3]. The FloTrac/EV1000™ monitoring system can measure the cardiac output (CO) based on the results of arterial-pressure waveform analysis, and can provide the SVV. The SVR and SVRI can also be calculated in the presence of the central venous pressure [4].

Therefore, in the current study, the changes that occur in the hemodynamic parameters when a patient assumes a prone position from a supine position were examined using the FloTrac/EV1000™ system, under general anesthesia.

MATERIALS AND METHODS

The current study was approved by the Institutional Review Board of our hospital, and the written informed consent of all the patients was obtained. A total of 56 adult patients with American Society of Anesthesiologists (ASA) physical status I-II and who require both arterial and central lines for elective lumbar-spine surgery were enrolled in the study from June 2013 to November 2014. The exclusion criteria included ASA physical status III or IV, significant cardiac diseases (e.g., heart failure, arrhythmia), anesthetics allergy, severe organ insufficiency, type II hypertension (systolic blood pressure ≥ 160 mmHg or diastolic blood pressure ≥ 100 mmHg) [5], and diabetic neuropathy.

The patients with hypertension continued their anti-hypertensive medication, except angiotensin-converting enzyme inhibitor (ACEI) or angiotensin II antagonists (AIAs), until the morning of the
surgery. All the patients were given premedication with oral triazolam 0.25 mg 60 minutes before being transported to the operating room. Support stockings were placed on the patients’ lower extremities. Throughout the operation, the patients underwent standard monitoring, including electrocardiography, non-invasive systemic blood pressure measurement, pulse oximetry, capnography, and bispectral index (BIS) monitoring. The BIS monitoring was started before the induction of anesthesia, using a BIS® monitor (Model A-2000; 3.31 software version; Aspect Medical System, Inc., Natick, MA, USA). The patients were given Plasma Solution A® at a rate of 5 ml/kg/hr throughout the study. After pre-oxygenation, propofol 2 mg/kg intravenous (IV) bolus was given, and remifentanil infusion was started at 3.0 ng/ml through effect-site target-controlled infusion (TCI). Intubation was done after the administration of rocuronium 0.6 mg/kg IV bolus. The ventilation was controlled to maintain an end tidal CO₂ of between 35 and 40 mmHg. Inhalation anesthesia was maintained with sevoflurane in oxygen to achieve a BIS reading of between 40 and 60.

After the induction of anesthesia, a 20-gauge catheter was placed in the radial artery and was connected to the FloTrac™ system (Edwards Lifesciences, Irvine, CA, USA) and the EV1000™ clinical platform (Edwards Lifesciences). The pressure transducer was placed at the mid-axillary line. A central venous catheter (ARROW Gardblue® catheter; Arrow International Inc., Reading, PA, USA) was placed in the right internal jugular vein and was connected to the EV1000™ clinical platform. The MAP, HR, cardiac index (CI), SVV, SVRI, and peak airway pressure (Ppeak) were measured. The hemodynamic parameters were measured 20 minutes after anesthesia induction in a supine position, and then 20 minutes after prone positioning, when the hemodynamics was already stable. The bolster system were consisted of rolled-up blankets, and the diameter of the bolster system was determined by the size of the patient. Measurement was done after prone positioning and before starting the surgery, and the patients were not given vasopressor treatment during the measurement. The TCI effect-site concentrations of remifentanil were adjusted to keep the MAP within 20% of the pre-induction value. When hypotension (MAP < 50 mmHg) occurred, it was treated with a bolus of ephedrine (8 mg) and with rapid fluid infusion. Ephedrine was repeated every 2 minutes if hypotension persisted or recurred.

**Statistical analysis**

The sample size calculation was based on the primary endpoint (CI). Based on the results of the pilot study (N = 5) that was conducted, to detect a mean difference ± standard deviation in CI of 0.3 ± 0.08 L/min/m² with a power of 80% at an α level of 0.05, 56 patients were required. Considering dropouts, 59 patients were recruited. The sample size was determined by “G power.”

Statistical analysis was done using SPSS for Windows ver.21.0 (SPSS Inc., Chicago, IL, USA). All the data were expressed as mean ± SD. Paired t-test was used to analyze the differences between the two positions. P value < 0.05 was considered statistically significant.

**RESULTS**

The patients’ demographic characteristics are shown in Table 1. Of the 59 patients, one patient was excluded due to the unsuccessful cannulation of the internal jugular vein, and another two due to the malfunction of the monitoring system.

There were significant differences in the CVP (5 ± 3 vs. 7 ± 3 mmHg) (P < 0.05; P = 0.001) and Ppeak between the supine and prone positions (13 ± 2 cmH₂O vs. 15 ± 2 cmH₂O) (P < 0.05; P = 0.000).

The MAP, HR, CI, SVV, and SVRI did not change after the patients assumed a prone position (Table 2).

**Table 1. Demographic Characteristics of the Patients**

| Characteristic                        | Data          |
|--------------------------------------|---------------|
| Gender (M/F)                         | 22/34         |
| Age (yr)                             | 65 ± 10       |
| Height (cm)                          | 158 ± 10      |
| Weight (kg)                          | 61 ± 10       |
| BMI (kg/m²)                          | 25 ± 4        |
| ASA (I/II)                           | 10/46         |
| Underlying disease                   |               |
| Hypertension                         | 23            |
| Diabetes                             | 18            |
| Chronic obstructive pulmonary disease| 2             |
| Preoperative medication              |               |
| β-blocker                            | 2             |
| Calcium channel blocker              | 8             |
| ACEI or AllAs                        | 19            |

The values are mean ± SD or number of patients. BMI: Body mass index, ASA: American Society of Anesthesiologists, ACEIs: Angiotensin-converting enzyme inhibitors, AllAs: Angiotensin II antagonists.
The hemodynamic changes from the supine to the prone position were examined using the FloTrac/EV1000™ system, and no changes were found, except an increased CVP. Most of the previous relevant studies showed that the SV, CI [6], and blood pressure [7,8] decrease when patients are made to assume a prone position. When a patient assumes a prone position, the arterial pressure can remain stable, but the CO usually decreases due to the reduced venous return. Abdominal compression with partial inferior vena caval obstruction [9] or attenuated sympathetic activation by general anesthesia [10] is considered the etiology.

No changes in the hemodynamics were observed, however, in the prone position. The differences in the study results may be due to the fact that different body positions and frames were used [11]. In the current study, a longitudinal bolster frame was used, and the patient’s legs were positioned above the heart. When a patient’s arms and legs are positioned lower than the heart, pooling of the intravascular volume occurs in the extremities, and the preload and SV can decrease [6].

Regarding the frames, some suggested that the SV decreases when patients are placed on a convex saddle frame [6,8,12]. In the current study, a longitudinal bolster device that partially supports the chest and pelvis, partially compresses the abdomen, and positions the legs above the heart was used. Consistent with the results of the present study, Dharmavaram et al. [8] showed that the longitudinal bolster device has a minimal effect on the cardiac performance. Toyota and Amaki [7] reported that the patient’s assumption of a flat prone position and the use of a longitudinal bolster device caused no changes in the hemodynamic parameters, such as the CI, SV, and SVRI. It is believed that a longitudinal bolster device only mildly compresses the abdomen, and that the fact that the legs were positioned above the heart prevented venous pooling and allowed adequate venous return. Yokoyama et al. [12] directly measured the pulmonary arterial and inferior vena cava pressure and revealed that while there are no hemodynamic changes when a flat frame is used, frames with a convex curvature result in a significant reduction in CI.

The CVP is a right-sided filling pressure [13]. Inconsistent with the previous reports, the CVP increased with the prone position in this study. The CVP is determined by the interaction between the cardiac function and the venous return, and the venous return is determined by the blood volume and the compliance of the venous system.

In this study, the CVP and SVV were found not to be correlated. The CVP is a static marker of the cardiac preload while the SVV is a dynamic marker of the cardiac preload. The CVP has lost favor as a hemodynamic marker [14]. According to McNulty et al. [11], there is no evidence that the CVP is a useful indicator of the ideal prone position in patients undergoing lumbar laminectomy. Therefore, the CVP is not a reliable monitoring tool during surgery in a prone position. It is presumed that the temporary jugular distension due to the prone position would increase the CVP, but this requires longer periods of observation.

The results of the study also showed that there was an increase in the Ppeak. In the patients who had been placed in a prone position using chest rolls such as a longitudinal bolster, there was an increase in the Ppeak and a decrease in the pulmonary compliance [15]. Unless the abdomen hangs freely, it is partially compressed by the supportive devices. Moreover, the increase in the Ppeak should not be attributed only to the decrease in compliance caused by the prone position but also to the increase in Raw caused by the drainage of secretive fluids due to gravity from the change in body position, as well as to the location and kinking of the endotracheal tube [16].

For the limitations of the current study, the accuracy of the measurement of the hemodynamic parameters using FloTrac™ can be questioned. FloTrac™ has reported a good correlation with the pulmonary artery catheter [17]. Further studies using the FloTrac™ and thermodilution methods simultaneously are required, however, to prove the usefulness of FloTrac™ in the prone position. Second, in this study, the hemodynamic para-

| Table 2. Hemodynamic Parameters and Peak Airway Pressure |
|---------------------------------------------------------|
| Supine | Prone |
| MAP (mmHg) | 86 ± 16 | 90 ± 20 |
| HR (beats/min) | 70 ± 12 | 68 ± 14 |
| CVP (mmHg) | 5 ± 3 | 7 ± 3* |
| CI (L/min/m²) | 2.7 ± 0.9 | 2.5 ± 0.7 |
| SV (%) | 10 ± 5 | 11 ± 6 |
| SVRI (dyne-s/cm⁵) | 2,576 ± 898 | 2,792 ± 824 |
| Ppeak (cmH₂O) | 13 ± 2 | 15 ± 2* |
| BIS | 49 ± 8 | 50 ± 9 |

The values are mean ± SD or number of patients. MAP: Mean arterial pressure, HR: Heart rate, CVP: Central venous pressure, CI: Cardiac index, SVV: Stroke volume variation, SVRI: Systemic vascular resistance index, Ppeak: Peak airway pressure. *P < 0.05 at the paired t-test.

DISCUSSION

The hemodynamic changes from the supine to the prone position were examined using the FloTrac/EV1000™ system, and no changes were found, except an increased CVP. Most of the previous relevant studies showed that the SV, CI [6], and blood pressure [7,8] decrease when patients are made to assume a prone position. When a patient assumes a prone position, the arterial pressure can remain stable, but the CO usually decreases due to the reduced venous return. Abdominal compression with partial inferior vena caval obstruction [9] or attenuated sympathetic activation by general anesthesia [10] is considered the etiology.

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meters were recorded only once after placing the patients in a prone position. A change may occur in the hemodynamic values as the operation proceeds. Further studies are therefore warranted to examine the serial changes in the hemodynamic parameters during surgery.

In conclusion, the study results indicate that prone positioning does not result in significant changes in the hemodynamic parameters measured using FloTrac™.

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