Systemic and cerebral effects of the head-down and head-up positions in ischemic heart patients under anesthesia

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ABSTRACT

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In cardiac surgery, head-down and head-up positions are used to control cardiac filling pressure and for cardiac exposure. Even though benefits of head positioning are not clear, they can also bring some risks. Understanding physiological consequences of positioning can help avoiding serious adverse events and complications. In this prospective study we investigated the effect of head-down and head-up position upon systemic and cerebral haemodynamics and cerebral oxygenation and their correlation with Bispectral Index (BIS) in CABG patients under general anesthesia before surgical incision. Thirty patients were enrolled in to the study. After induction and before surgical incision blood pressure, heart rate, central venous pressure, cardiac output, stroke volume variation, BIS, cerebral oxygen saturation and middle cerebral artery blood flow rate values of the study patients were measured at neutral, head-down and head-up positions. The significance of the difference in terms of the means between the positions was studied with the repeated measures analysis of variance, while the significance of the difference in terms of the mean values was analyzed with Friedman test. Statistically significant increase were recorded in blood pressure, cardiac output, central venous pressure, cerebral blood flow rate and BIS values in the head-down position. The head-up position was associated with decrease in cardiac output. We demonstrated that both positions are safe for cerebral haemodynamics and oxygenation in ischemic heart patients. We showed that the short term head-down position can improve cardiac

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function, probably due to increased preload in ischemic heart patients with normal ejection fraction; however, the head-up position can be detrimental for systemic haemodynamic even for a short period.

INTRODUCTION

In cardiac surgery, head-down and head-up positions are used to control cardiac filling pressure and for cardiac exposure. Even though benefits of head positioning are not clear, they can also bring some risks[1,2]. Understanding the physiological consequences of positioning can help to prevent serious adverse events and complications.

The Trendelenburg position (head-down position) was originally described by Friedrich Trendelenburg, as a method of improving the view of surgical field during laparatomy[3]. It was suggested by Walter Cannon as a method of improving cardiac output in patients with shock, during the First World War, although he reversed this idea a decade later[4]. Despite the fact, numerous studies having failed to show its effectiveness[5,6], the head-down position is frequently used in cardiac surgery to treat hypotension, in order to raise blood pressure and cardiac output[7]. Lim TW et al reported that head-down position provided also more stable anesthetic induction during cardiac surgery and could decrease vasopressor requirements[8].

The head-up position during anesthesia, can be beneficial by decreasing intracranial pressure in patients with intracranial hypertension[9]. It is also used to improve cardiac swelling with decreased cardiac filling pressure in cardiac surgery. However, the head-up position can severely compromise cerebral perfusion pressure and cerebral tissue oxygenation[10].

In this study, we hypothesised that the head-up position might have a detrimental effect on cerebral haemodynamic homeostasis and the head-down position might have a placebo effect on systemic haemodynamic homeostasis. We investigated the effects of both short term head-down and head-up positions on systemic haemodynamic, cerebral blood flow rate and oxygenation in the ischemic cardiac patients under general anesthesia and their correlation with BIS values.

MATERIAL AND METHODS

This study was approved by the ethics committee of the Türkiye Yüksek İhtisas Training and Research Hospital (approval number 2549) and written informed consent was obtained by all study patients. We enrolled 30 elective CABG patients in ASA II -III group, aged over 20 years, into this study. The exclusion criteria were as follows: ejection fraction (EF) < 40%, arrhythmia, uncontrolled hypertension, major organ damage (creatinine > 2 $mg.dl^{-1}$, aspartate aminotransferase (AST-SGOT) > 40 U.L^{-1}, alanine aminotransferase (ALT- SGPT)> 40U.L^{-1}), Hct < 30%, drug allergy, neuromuscular disease, cerebrovascular events, psychiatric or neurological drugs usage. The patients were assessed the night before surgery and were informed about the study and the anesthetic method to be administered.

Patients were premedicated with morphine 0.1 mg.kg^{-1} i.m 30 min before anesthesia induction. Diazepam 5–10 mg p.os. was administered the night before surgery. In the operating theatre, after routine monitoring and obtaining IV access, radial artery catheterization was carried out using a 20 gauge arterial cannula. A non-invasive cardiac output monitor (FloTrac /Vigileo monitor) is connected to arterial system and used. A pulse oxymeter probe was inserted in the forefinger in the extremity in which the artery was not accessed. Regional cerebral oxygen saturation was assessed continuously, using the INVOS cerebral oximeter (Oxygen saturation values for the left (rSO_2left) and right hemispheres (rSO_2right) (INVOS, cerebral Oximeter Device) and bispectral index (BIS) monitoring (Datex Ohmeda) were applied. The middle cerebral artery (MCA) blood flow rates were measured with 2MHz wavelength prob using HP Sonos 1000 ultrasound system. The measurements were taken from the most appropriate image data point of the zygomatic arch in the right temporal lobe. Subsequent measurements were performed at the same depth (50-55 mm) through the same vessel segments.

After monitoring process patients were preoxygenated with 100% oxygen (10 L/min) for two minutes. A balanced electrolyte solution (Isolyte S) was infused at a rate of 30 ml.kg.h^{-1} during anesthetic induction, which was achieved with 0.1 mg.kg^{-1} midazolam, 5 -7 μgr.kg^{-1} fentanyl and 0.7 mg.kg^{-1} rocuronium for muscle relaxation. After endotracheal intubation, patients were ventilated with 50% oxygen/air mixture as the tidal volumes being 8 ml.kg^{-1}, no positive end-expiratory pressure (PEEP) was applied. None of the patient is needed additional anesthetics, as BIS values were lower than 60. The ventilation rate was adjusted to $ETCO_2$ 35-37 mmHg. Nasopharyngeal temperature was adjusted with a blanket, as not to fall below 36 C^o. Following intubation, internal jugular vein cannulation was performed for CVP monitoring.

Baseline data; systolic blood pressure (SBP), diastolic blood pressure (DBP), mean blood pressure (MBP), heart rate (HR), central venous pressure (CVP), cardiac output (CO), stroke volume variation (SVV), BIS index, rSO_2left, rSO_2right, systolic, diastolic and mean MCA blood flow rates (Vmean, Vs, Vd) were measured and recorded in the neutral position, immediately after anesthesia induction and central venous cannulation. The pulsatility and resistivity index (PI and RI) were calculated by software of the device. After the neutral measurements patients were placed 30º head-down position for 5 minutes, then second measurements were carried out. Patients repositioned as neutral for 3 minutes and then 30º head-up position is applied for 5 minutes then third measurements were carried out.

Statistical Analysis

Data analysis was performed through the Statistical Package for Social Science (SPSS) for Windows 11.5 soft ware. The normality of distribution of continuous variables was examined via Shapiro Wilk test. Descriptive statistics for continuous variables were expressed as mean ± standard deviation and minimum-maximum, while nominal variables were expressed as the number of cases and percentage (%).

The significance of the difference in terms of the means between the positions was studied with the repeated measures analysis of variance, while the significance of the difference in terms of the mean values was analyzed with Friedman test. In cases of the results being found significant using repeated measures analysis of variance or Friedman test, the causes of difference was defined using multiple comparisons of the Bonferroni correction or Wilcoxon test. Spearman's Correlation test was used to search to determine whether there was a correlation between the continuous variables.

The results were accepted statistically significant for $p < 0.05$. The Bonferroni correction was applied in order to control Type I error in all the possible multi-comparisons.

RESULTS

Thirty patients udergoing CABG surgery were enrolled into this study. Patient characteristics and comorbidities are described in Table 1.

Table 1. Patient's demographic data

VARIABLES	PATIENTS (N=30)
AGE (yrs) (mean±SD)	56.9 ± 10.6
GENDER [N,(%)]	
MALE	23 (76.7%)
FEMALE	7 (23.3%)
ASA[N,(%)]	
II	18 (60%)
III	12 (40%)
HT [N,(%)]	17 (56.7%)
HISTORYOF OPERATİON [N,(%)]	9 (30%)
HEIGHT*(cm) (mean±SD)	166.5 ± 7.1
WEIGHT(kg) (mean±SD)	75.7 ± 14.5
BMI(kg/m^2) (mean±SD)	27.2 ± 4.4
NUMBEROF ARTERIES BYPASSED	3 (1-3)
NYHA [N,(%)]	
I	1 (3.3%)
II	29 (96.7%)

N:number of cases, %: percentage, HT: Hypertension, NYHA: New York Heart Association

Systemic Haemodynamics

Significant increases were found in SBP, DBP, MBP and a significant decrease in heart rate in the head-down position compared to the neutral (Table 2).No significant difference was observed between neutral and head-up positions in terms of SBP, DBP, MBP and HR (Table 2).SVV levels did not differ significantly between the positions (Table 2).

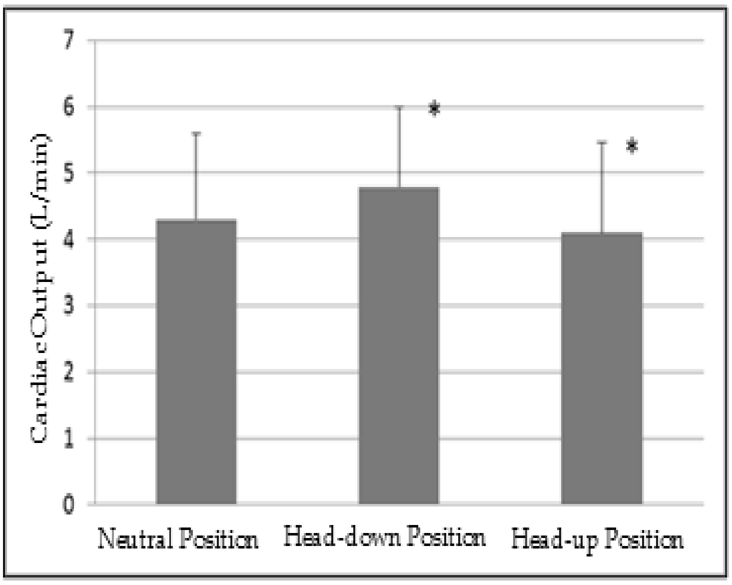
Table 2. Distribution of clinic parameters according to the positions**.**

Parameters	Neutral position	Head-down position	Head-up position	p value
SBP (mmHg)	116.0 (19.1)	127.3 (18.2)[a]	107.4 (19)	0.001
DBP (mmHg)	62.5 (10.6)	67.8 (11.4)[a]	57.7 (11.2)	0.001
MBP (mmHg)	86.4 (12.6)	95.0 (13.6)[a]	81.1 (13.3)	0.001
HR (beat/min)	73.3 (12.8)	65.7 (10.4)[a]	73.9 (13.6)	0.001
CO (L/min)	4.3 (3.2-8.8)	4.8 (3.1-8.4)[a]	4.1 (1.8-8.0)[b]	0.001
SVV (%)	12 (5-23)	11 (3-30)	12 (6-24)	0.068
CVP (cm H_2O)	8.2(3.0)	10.9(3.2)[a]	6.6(2.1)[b]	0.001
BIS	43.7(7.6)	54.9(8.1)[a]	48.6(7.7)[b]	0.001
NIRS-Left (%)	60.4(6.3)	59.5(5.3)	55.5(7.1)[b]	0.008
NIRS-Right (%)	61.7(7.4)	61.3(6.5)	56.2(8.5)[b]	0.005
Vs (cm/sec)	59.5 (30-112.9)	67.6 (46-136)[a]	65 (36-113)	0.001
Vd (cm/sec)	20.6 (7-46.6)	21.3 (10-45.8)	18.1 (7-40)	0.224
Vm (cm/sec)	31 (13-71.8)	36.6 (23-71.0)[a]	32 (11-58.5)	0.011
TCD-PI	1.2 (0.8-2.4)	1.2 (0.8-2.9)	1.2 (0.6-2.9)	0.967
TCD-RI	0.7±0.08	0.7±0.08	0.7±0.09	0.884

CO, SVV, Vs, Vd, Vm, TCD-PI are expressed as mean (minimum-maximum), rest of the data are expressed as mean(SD). a: Difference between neutral and head-down positions was statistically significant (p < 0.05), b: Difference between neutral and head-up positions was statistically significant (p < 0.05).

A significant increase was seen in cardiac output in the head-down position compared to neutral position (p = 0.047). A significant decrease was observed in cardiac output in the head-up position compared to neutral position (p = 0.002), (Figure 1).

Figure 1. Cardiac output values according to patients positions



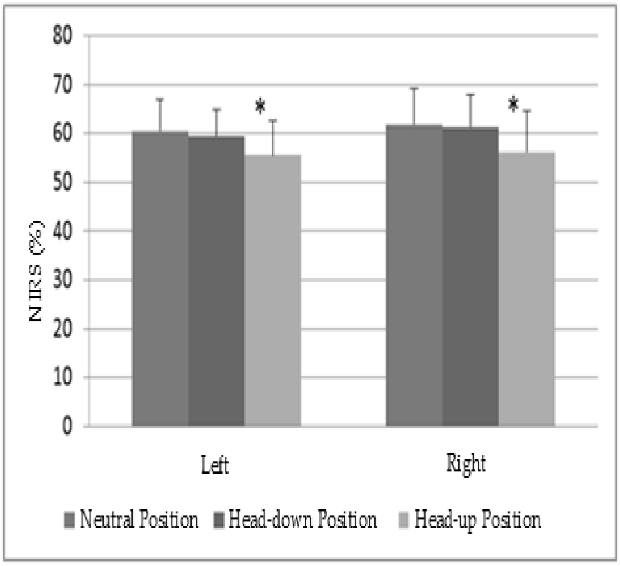
**p < 0,05*

A significant increase was found in mean CVP in the head-down position compared to the neutral position (p < 0.001). A significant decrease was found in mean CVP in the head-up position compared to the neutral position (p = 0.004), (Table 2).

Cerebral Haemodynamics and Oxygenation

A significant decrease was observed in NIRS-left and NIRS-right in the head-up position compared to the neutral position (p = 0.005, p = 0.004), no significant difference was found in NIRS values between the neutral and head-down positions (p = 1.000) (Table 2, Figure 2).

Figure 2. NIRS values according to patients positions



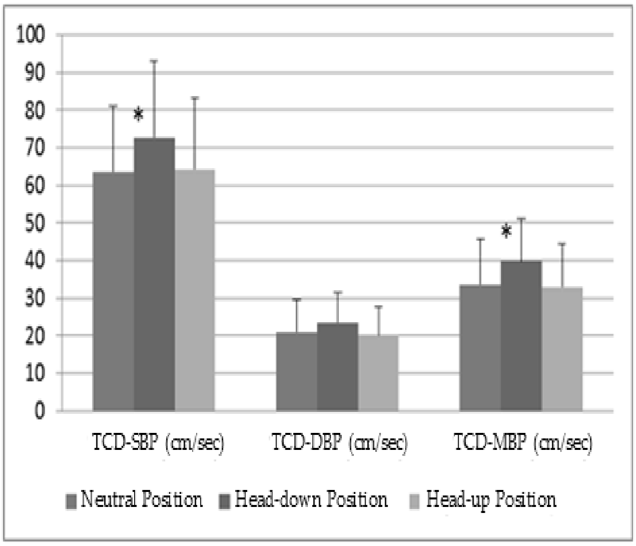
**p < 0,05*

A significant increase was found in TCD-Vs and TCD-Vmean in the head-down position compared to the neutral position (p = 0.005, p = 0.021 respectively) but TCD-Vd. No significant difference was found in TCD-Vs, TCD-Vd, TCD-Vmean values between the neutral and the head-up position (Table 2, Figure 3). No statistically significant difference was observed among the positions in terms of the levels of TCD-PI and TCD-RI (Table 2).

BIS Values

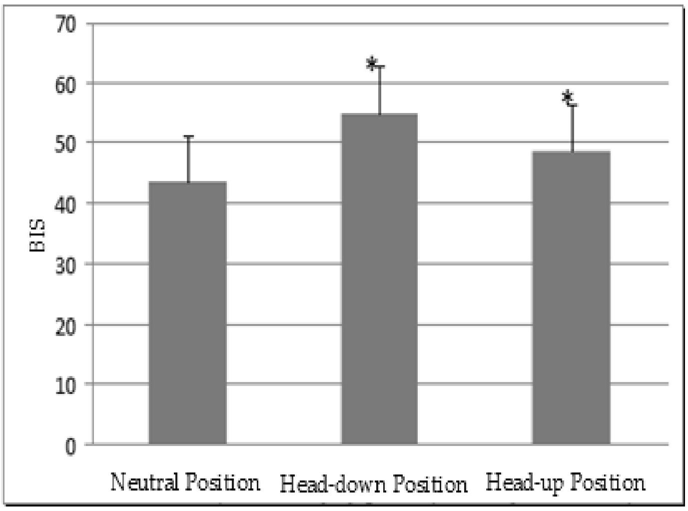
There were significant increases in mean BIS values in head-down and head-up positions compared to the neutral position (p < 0.001, p = 0.002), (Table 2, Figure 4). BIS value in the head-down position was correlated only in the change of DBP value and BIS increased by the increasing of DBP (r^2 =0.428 ve p =0.018).

Figure 3. TCD SBP(Vs), DBP (Vd) and MBP (Vmean) values according to patients positions



**p < 0,05 TCD: Transcranial doppler, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, MBP: Mean blood pressure*

Figure 4. BIS values according to patients positions



**p < 0,05*

No significant correlation was observed between BIS value and the other changes in the measured values (p>0.017) (Table 3).

Table 3. Correlation coefficients between the BIS changes and other measured parameters in the head-up position compared to neutral position

Parameters	Correlation Coefficient (r)	P values
SBP (mmHg)	-0.018	0.927
DBP (mmHg)	-0.116	0.541
MBP (mmHg)	0.094	0.620
Heart Rate (pulse/min)	0.215	0.255
Cardiac Output (L/min)	0.171	0.368
SVV (%)	0.074	0.699
CVP (cm H_2O)	0.168	0.375
NIRS-Left (%)	0.487	0.006
NIRS-Right (%)	0.307	0.099
TCD-SBP (cm/sec)	0.365	0.047
TCD-DBP (cm/sec)	0.310	0.096
TCD-MBP (cm/sec)	0.288	0.123
TCD-PI	-0.082	0.668
TCD-RI	-0.063	0.740

DISCUSSION

In this study we assesed the effects of head-down and head-up positioning on systemic and cerebral haemodynamic, in patients undergoing elective CABG surgery after anaesthesia induction. The head-down position increased arterial blood pressure, central venous pressure, cardiac output (CO) and decrease heart rate (HR) significantly. These results suggest increased preload. The head-up position decreased arterial blood pressure, central venous pressure and cardiac output, but there was statistical significance was noted only in CO and HR. These results suggest decreased preload. Similarly Lim et al.[8] showed that, the head-down position has crucial effects in prevention of hypotension, as well as reduction in the vasopressor dosage and made the anesthesia induction safer during elective coronary artery bypass and valvular surgeries. Senn et al,[11] found that cardiac output was significantly increased in the head-down position and significantly decreased in the head-up position, in patients after off-pump coronary artery bypass surgery, by the FloTrac/Vigileo™ and the PiCCOplus™ system. Mekis et al[12] defined significant increases in mean arterial pressure, cardiac output, CVP and pulmonary artery wedge pressure during shifting from 20º head-up to 20º head-down position in patients undergoing CAGB surgery. In conclusion our study and the other studies demonstrated that head-down position is an advantage for hypotension following general anesthesia.

In the present study, CVP increased in the head-down and decreased in the head-up position. These results can be attributed to the blood accumulation. However SVV was stable in both positions. The stroke volume variation

(SVV) is one of the dynamic parameters of fluid status. SVV has been shown to have a very high sensitivity and specifity, when compared to traditional indicators of volume status (HR, MAP, CVP, PAOP) and their ability to determine fluid responsiveness[7]. SVV is not an indicator of actual preload but of relative preload responsiveness. Our study supports those findings as being stable SVV in stable volume status patients. Hofer et al.[13] found significant decrease in SVV when the patient position change from 30º head-up to 30º head-down in open heart surgery patients. Daihua Y et al demonstrated that the head-up position significantly increased SVV with a strong negative correlation between SVV and Cardiac Index (CI), Stroke Volume Index (SVI), Global Ejection Fraction (GEF) and Global End Diastolic Volume Index (GEDVI)[14].

Patient positioning can have significant adverse effects on cerebral perfusion and oxygenation. In this study we showed the effects of short term head-up and head-down positions on cerebral perfusion with NIRS and transcranial doppler. NIRS is used widely, has important advantages because it shows cerebral perfusion and is a noninvasive technique[15]. Many studies demonstrated that the head-down position increases intracranial and intraocular pressure[16,17] and middle cerebral artery flow velocity[18]. Fuchs et al.[19] showed that the head-up position under isoflurane anesthesia decreases cerebral perfusion. Our study showed that NIRS values did not change in the head-down position but decreased in the head-up position. It was found in the patients undergoing laparoscopic surgery that the head-down position did not affect intracranial circulation. This important outcome proves that the head-down position is a safe positions in terms of NIRS values[20]. Tange et al.[21] found that the head-up position did not decrease cerebral oxygenation under general anesthesia, in patients having normal preoperative cerebral oxygen index. In our study, the head-up position decreased statistically significantly NIRS-left (60.4 (6.3) to 55.5 ± 7.1) and NIRS-right (61.7 ± 7.4 to 56.2 ± 8.5), but clinically this decrease must be < 80% of baseline value to be meaningful. The decrease was lower than 20% of baseline for both hemisphers[22]. Moreover, TCD did not support this finding but clinically their results showed correlation. We found a significant increase in cerebral blood flow by TCD in the head-down position. Our study showed that short term 30° head-up and head-down positions do not have decrimental effects on cerebral oxygenation in ischeamic heart patients. Fuchs et al.[19] reported a significant decrease in cerebral oxygen saturation in sitting position under sevoflurane anesthesia which was absent among awake patients. They comment that autoregulatory mechanisms of the cerebral circulation can be corrupted during sevoflurane anesthesia. The difference between Fuchs's study and our study is the degree of positions; we could find clinically meaningful decrease in steep head-up.

Our results showed that after the head-down position BIS value and rate of cerebral arterial blood flow increased whereas cerebral oxygenation did not change. Kaki et al.[23] studied the effect of the position on BIS in ASA I-II patients. They used 30º head-down and 30º head-up position, after 15 minutes, they found significant increase in BIS values after head-down position and significant decrease in BIS in head-up position. They attributed these findings to the physiological changes associated with positions which are mainly related to changes in in blood flow. Similarly, our study demonstrated that head-down position significantly increases BIS values. But in the head-up position BIS values were greater than basal supine position but smaller than head-down position. The reason could be our short waiting time; 5 min was not enough to show the head-up effects after head-down.

The limitation of our study could be the short duration time in each position.

In conclusion, we demonstrated that short term head-down and head-up positions are safe for cerebral haemodynamics and oxygenation in ischemic heart patients under anaesthesia. The short term head-down position can improve cardiac function as increased preload in ischemic heart patients with normal ejection fraction; however, the head-up position can be detrimental for systemic haemodynamic even for a short period.

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