Original Article

The relationship between carotid artery colour Doppler finding and cerebral oximetry

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Abstract

Background: In some cases, permanent reduction in cerebral functioning affects a high percentage of patients undergoing cardiovascular surgery. We studied the relationship between the results of preoperative bilateral carotid artery colour Doppler sonography and regional cerebral oxygen saturation (rSO_2) during coronary artery bypass graft surgery (CABG).

Materials and Methods: This study was a cross-sectional analytical study conducted with 96 candidates for off-pump CABG. This study determined the percentage of the correlation of rSO_2 with demographic information, diabetes, hyperlipidemia, hypertension, myocardial infraction (MI), and smoking, and also provided information on the presence and type of plaque, intima-media thickness (IMT), and percentage of stenosis of carotid artery detected through colour Doppler sonography. Data were analyzed by the *t*-test, the Chi-square test, and simple linear regression.

Results: In this study, the mean value of rSO_2 increased after intubation compared to the mean before intubation, the difference being statistically significant ($P = 0.005$). A comparison of the mean rSO_2 of the right side of the brain and the percentage of right carotid obstruction (stenosis of less than 50% vs. stenosis with a range of 50-69%) revealed that the mean rSO_2 at the time of the partial-clamp between carotid stenosis less than 50% and carotid stenosis with a range of 50-69% was statistically significant ($P = 0.043$).

Conclusions: There is no statistically significant correlation between rSO_2 and percentage of carotid artery stenosis less than 70%. It is advised that rSO_2 and carotid stenosis of greater than 70% be studied in future.

Key Words: CABG, carotid artery, cerebral oximetry, colour Doppler sonography

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INTRODUCTION

Cerebral damage following cardiovascular surgery is a life-threatening event correlated with increased lengths of hospital and ICU stay, and increased mortality rates.[1] Cerebral oxymetry is a means of investigating regional cerebral blood circulation, digitally showing the regional cerebral hemoglobin

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oxygen saturation through continuous assessment of cerebral blood circulation. Hence, the application of cerebral oxymetry can not only help in early diagnosis and prompt intervention before established neurological consequences, but also lead to reduced incidence of neurological complications and a decreased length of hospital stay.[2] Also, some studies consider carotid artery disorders as risk factors for the incidence of neurological conditions. These studies state that the true prevalence of carotid artery disease (CAD) is 17%-22%[3,4] and that the total incidence of cerebrovascular complications is 1%-6% after coronary artery bypass graft surgery (CABG),[5] while the obvious involvement of the carotid artery is approximately responsible for 1% of all cerebrovascular accidents. Despite this contradiction, it seems that a survey of CAD before CABG is of high importance.[6] The permanent reduction of cerebral function affects a high percentage of patients undergoing cardiovascular surgery. The costs of cerebral damage due to cardiovascular surgery are high. Thus, there are many clinical and economical motivations for studying the role of neurophysiologic monitoring to protect the brain during cardiovascular surgery. The debate over a correlation between stenotic carotid artery disorders and the incidence of cerebrovascular accidents after CABG surgery is still controversial. A number of studies have stated that carotid stenosis is a risk factor at the cross-sectional level by 50% or more for the creation of cerebrovascular complications after cardiovascular surgery.[7,8] Therefore, this study was designed to investigate the findings of preoperative bilateral carotid artery colour Doppler sonography and also the amount of cerebral oxygen saturation measured by cerebral oximetry during surgery (INVOS 5100, somanetic Corp, Tory, MI, USA), and to compare the correlation between the findings by these two methods.

MATERIALS AND METHODS

This was a cross-sectional analytic study conducted on 96 patients who were candidates of CABG, after obtaining both the approval of the Committee of Ethics at Yazd University of Medical Sciences and informed written consent from each candidate. Data collection was according to simple randomized sampling. The patients with a history of drug addition, cerebral surgery, and congenital disorders were excluded from the study. Demographic information including previous history of cerebrovascular complications, diabetes, hypertension, peripheral vessels diseases, and smoking were recorded in a questionnaire the day before surgery. Furthermore, data relating to the presence and type of plaque, intima-media thickness (IMT), percentage of common carotid artery obstruction, and internal and external carotid artery stenosis were measured and recorded with color Doppler sonography using the Siemens G40 Color Doppler device. To measure cerebral oxygenation, INVOS 5100 (Somanetics Corp., Troy, MI, USA) was used. For induction of anesthesia, etomidate with a dose of 0.2-0.3 mg/kg and an infusion bolus of remifentanyl 1 μ/kg were used for both groups. For muscle relaxation, Pancuronium bromide 0.15 mg/kg was used. To repeat the muscle relaxant, Pancuronium bromide 0.01 mg/kg was used every 60 min. The mean arterial pressure (MAP) was maintained at 50-100 mmHg. Hypotension, sufficient fluid infusion, and phenylephrine 100 μg and/or intravenous ephedrine 10 mg were used. Hypertension was managed with a bolus of trinitroglycerin (TNG) 100-200 μg. Before the initiation of the first anastomosis, heparin 150 IU/kg of body weight was given to maintain activated clotting time (ACT) for longer than 250 s. On completion of anastomosis, ACT was reduced to 150-170 with the administration of protamine. The surgical technique was the same for all patients and all the anastomoses were performed using intracoronary shunt. The percentage of regional cerebral oxygen saturation (rSO_2) was recorded for all patients before induction, after induction, during left anterior descending artery bypass (LAD) graft surgery, during posterior descending artery (PDA) bypass graft surgery, during circumflex (CX) bypass graft surgery, and also during partial aortic clamp for proximal anastomosis. Data were analysed by the *t*-test, the Chi-square test, and simple linear regression.

RESULTS

The mean age of patients was 62.41 ± 10.18 years (with a range of 37-78 years). The mean ejection fraction (EF) was 43.93 ± 10.05% (range 20-62%). Fifty-six (58.3%) patients were male and 40 (41.7%) were female. The frequency distribution of the number of grafts showed that 47 patients were three-grafted, 46 patients were two-grafted, and three patients were one-grafted. The frequency distribution of the number of patients with plaque diagnosed by sonography demonstrated that 34 patients had plaque and 62 patients were plaque-free. Of the former, 26 patients showed hypoechoic plaque, seven patients had hyperechoic plaque, and one patient had ulcerative plaque. The results of frequency distribution of plaque sites revealed that 14 patients had their plaque in the right carotid artery, 10 patients in the left carotid artery, and 10 patients in both the right and left carotid arteries. Regarding the percentage of stenosis of carotid arteries in terms of risk factors of hypertension, hyperlipidemia, smoking, and MI, it could be said that although the percentage of stenosis in patients with hypertension, hyperlipidemia, and diabetes was higher than that of the patients without these risk factors, the difference was not statistically

significant. The mean percentage of cerebral oxygen saturation was 65.81 before anaesthesia. Also, the mean rSO_2 increased after intubation compared to before intubation, causing a statistically significant difference (P = 0005). The results of frequency distribution of percentage of carotid artery stenosis obtained from the ratio of peak systolic velocity/internal carotid artery (PSV/ICA) to peak systolic velocity/common carotid artery (PSV/CCA) revealed that for the right carotid artery, 70 patients had stenosis less than 50% and 26 patients had stenosis 50-69%. Regarding the left carotid artery, 61 patients had stenosis less than 50% and 35 patients had stenosis 50-69%. The results of comparison of the mean rSO_2 of the right hemisphere and percentage of right carotid stenosis (stenosis less than 50%, stenosis 50-69%) revealed that the mean rSO_2 values before and after induction, during LAD graft, CX graft, and PDA graft were not significantly different, yet there was a significant difference at the time of aortic partial clamp (P = 0.043) [Table 1]. Additionally, the results of comparison of mean rSO_2 of the left side of the brain and percentage of stenosis of right carotid artery (stenosis less than 50%, stenosis 50-69%) revealed that there was no significant difference at any of the desired times [Table 2]. The frequency distribution of status of IMT demonstrated that regarding the right carotid artery, 35 patients had normal thickness (less than 0.8), 61 patients had abnormal thickness (39 patients with thickness of more than 0.8 and less than 1.1, and 22 patients with IMT of more than 1.1). Furthermore, regarding the left carotid, 47 patients had normal IMT (less than 0.8), 49 patients had abnormal thickness (19 patients with thickness of more than 0.8 and less than 1.1, and 30 patients with IMT of more than 1.1) [Table 3]. The correlation coefficient between percentage of local oxygen saturation of the right side of the brain before induction, and IMT of the right carotid artery was r = 0.109, which was not significant at P = 0.291. This means that there was no statistically significant correlation between the percentage of rSO_2 of the right side of the brain before induction of anesthesia and IMT of the right carotid artery. Finally, there was no statistically significant correlation between the percentage of rSO_2 of the right side of the brain and the IMT of the right carotid artery, between the percentage of oxygen saturation of the left side of the brain before induction and the IMT of the left carotid artery after induction, during LAD graft, CX graft, PDA graft, and the time of aortic partial clamp [Table 4].

DISCUSSION

Regarding the percentage of carotid artery stenosis risk factors of hypertension, hyperlipidemia, smoking, and MI, although the percentage of stenosis was greater in patients with hypertension, hyperlipidemia, and diabetes compared to patients without these risk factors, the difference was not statistically significant. These findings were not consistent with the results of studies by Ohouchi, Kawarada, and Tournay.[9-11] This inconsistency may be due to our smaller sample volume, and consequently, due to the smaller percentage of carotid artery stenosis in our study, the percentage of carotid artery stenosis was less than 70% in our study. In addition, the percentage of stenosis was higher in our study in patients with smoking and MI compared to patients without smoking and MI, this being significantly different (P = 0.042, and P = 0.042). This finding was consistent with the results of Mitta *et al.*[12] The mean percentage of cerebral oxygen saturation was 65.81 before surgery, being consistent with the findings by Nauphal and Papadopoulos.[13,14] In the present study, the mean percentage of cerebral oxygen saturation was smaller in patients with diabetes compared to patients without diabetes (P = 0.012),

Table 1: Comparison of mean percentages of regional cerebral oxygen saturation of the right side of the brain in terms of percentage of stenosis of right carotid artery

rSO_2 Stenosis	Before induction*	After induction*	LAD*	CX*	PDA*	Partial clamp*
<50%	64.38±9.51	66.41±12.42	62.68±1.48	55.8±1.48	53.23±3.09	53.06±5.1
50-69%	65.76±8.97	71.56±10.15	62.2±9.35	57.91±10.2	61±6.99	59.72±9.49
P value**	0.528	0.36	0.878	0.09	0.055	0.043

*(Mean±SD). **_t_-test, rSO_2: Regional cerebral oxygen saturation, LAD: Left anterior descending artery, CX: Circumflex coronary artery, PDA: Posterior descending artery

Table 2: Comparison of mean percentages of regional cerebral oxygen saturation of the left side of the brain in terms of percentage of stenosis of right carotid artery

rSO_2 Stenosis	Before induction*	After induction*	LAD*	CX*	PDA*	Partial clamp*
<50%	66.15±7.15	69.93±9.68	64.74±1.151	56.88±6.89	60.16±5.97	58.18±4.37
50-69%	68.2±6.95	66.97±9.25	64.29±10.69	61.6±7.03	60.41±5.03	56.13±6.21
P value**	0.292	0.146	0.847	0.213	0.934	0.53

*(Mean±SD). **_t_-test, rSO_2: Regional cerebral oxygen saturation, LAD: Left anterior descending artery, CX: Circumflex coronary artery, PDA: Posterior descending artery

Table 3: Frequency distribution of intima-media thickness of the left and right carotid arteries

Thickness / Carotid artery	Normal	Abnormal	
	<0.8	1.1< IMT <0.8	>1.1
Right	35	39	22
Left	47	19	30

IMT: Intima-media thickness

Table 4: Determining the correlation coefficient between percentage of regional cerebral oxygen saturation and intima-media thickness of the carotid artery

rSO_2 Time	Left carotid artery		Right carotid artery	
	P value	*r*	*P* value	*r*
Before induction	0.747	0.033	0.291	0.109
After induction	0.758	−0.032	0.678	0.043
LAD	0.429	−0.082	0.091	−0.174
CX	0.39	−0.096	0.681	−0.046
PDA	0.231	−0.148	0.335	−0.12
Partial clamp	0.365	−0.095	0.547	−0.063

*Simple linear regression. LAD: Left anterior descending artery bypass, CX: Circumflex, PDA: Posterior descending artery

this being consistent with the findings of the study by Baikoussis.[15] Additionally, the mean rSO_2 increased after intubation compared to before intubation, the difference being statistically significant ($P = 0.005$). This increase may be due to the vasodilatory effect of anesthetics and the intake of 100% oxygen and also the reduced cerebral tissue consumption due to anesthesia. Among all the patients, 34 had plaque and 62 did not. Of the former, 26 patients had hypoechoic plaque, seven patients had hyperechoic plaque, and one patient had ulcerative plaque. Generally speaking, plaque refers to the increase of IMT by more than 1.1[16] and/or an increase in thickness by 50% more than the thickness of the adjacent vessel.[17] The risk of plaque-related ischemic accidents is highly dependent on the histological morphology of plaque (hypoechoic, hyperechoic, and ulcerative plaque). In hypoechoic plaque, a thin layer of fibrosis lies on a lipid nucleus, and macrophage and hemorrhagic areas are sometimes seen. Hyperechoic plaques have a dense fibrosis layer and calcification creating a sound shape.[18] The hypoechoic and heterogeneous plaques are associated with neurovascular and cerebral ischemic symptoms.[19] In assessing the percentage of rSO_2 performed separately for each hemisphere with the left and right carotid arteries, it was determined that there was no significant difference in the mean rSO_2 of the right side of the brain in terms of carotid plaque status (the presence of plaque in the left and right carotid arteries) before and after induction, and during PDA graft and at the time of performing partial clamp, while the difference was significant at the time of performing LAD graft ($P = 0.001$) and CX graft ($P = 0.020$). This difference may be due to the heart position in the desired positions. The percentage of carotid artery stenosis obtained on the basis of the ratio of PSV ICCA to PSV CCA, showed that regarding the right carotid artery, 70 patients had stenosis less than 50% and 26 patients had stenosis 50-69%. Regarding the left carotid artery, 61 patients had stenosis less than 50% and 35 patients had stenosis between 50% and 69%. The comparison of mean percentage of rSO_2 and percentage of the right carotid artery (stenosis less than 50%, stenosis of 50-69%) revealed that the mean percentages of regional oxygen saturation before and after induction, at the time of performing LAD, CX, and PDA grafts were not statistically different; yet, the difference was statistically significant at the time of partial clamp ($P = 0.043$). This means that carotid artery stenosis at the time of partial clamp decreases rSO_2, which may be due to low systemic blood pressure (80-90 mmHg) at the time of partial clamp. Several studies have reported the tangible correlation between PSV in the medial cerebral artery and rSO_2 at the time of partial clamp.[20-22] Regarding strength, the correlation between PSV in the medial cerebral artery and percentage of rSO_2 has been positive.

CONCLUSION

We found that the percentage of oxygenation was correlated with less than 70% stenosis of carotid arteries, yet, the difference was not statistically significant. Also, rSO_2 has a significant correlation with some of the heart positions in the off-pump CABG, like CX artery bypass graft and partial clamp. It is recommended that future studies with larger sample volumes and stenoses greater than 70% also be conducted. Also, computerized tomography (CT) angiography scans with rSO_2 should be investigated.

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