Original Article

Comparison of Carotid and Vertebral Artery Doppler Measurements in Supine and Sitting Positions

MA İkidağ, YE Fırat[1]

Departments of Radiology and [1]Neurology, SANKO University Hospital, Turkey

Abstract

Background: Carotid and vertebral Doppler ultrasonography (USG) is the primary diagnostic tool for the detection of extra cranial atherosclerotic disease and measurement of posterior fossa blood flow volume. The examination is performed while the patient lies on supine position. However, in daily practice we occasionally encounter patients who are not able to lie down on supine position for different reasons, such as kyphosis, severe dyspnea, or severe back pain. **Aim:** We aimed to compare the doppler spectral measurements of carotid and vertebral arteries obtained in supine and sitting positions. **Patients and Methods:** Fifty-three patients were recorded in the first group, to whom carotid and vertebral (CV) Doppler Ultrasound examination was initially performed while sitting, and another 52 patients were examined as the second group where initial measurements were done in a supine position. Peak systolic velocity (PSV), end diastolic velocity (ED) from each vessel, internal carotid artery (ICA)/common carotid artery (CCA) ratio, and volume flow of vertebral artery (VA) were measured in supine and sitting positions. Also, another 83 patients with a complaint of vertigo were included in the third group but only VA measurements were compared. **Results:** In the first group, there was a difference between sitting and supine positions in right ICA diastolic, right and left VA diastolic, and left CCA diastolic velocities ($P < 0.05$). In the second group, there was a difference in sitting and supine positions in right CCA systolic, right CCA diastolic, and left CCA diastolic velocities ($P < 0.05$). In the third group, there was a difference in sitting and supine positions in right and left VA diastolic velocities, left VA volume flow, and total VA volume flow ($P < 0.05$). A strong correlation was detected between supine and sitting positions regarding right and left ICA stenoses. Alterations in waveforms were noted in three patients' unilateral VAs, in supine and sitting positions. **Conclusion:** Our results suggest that CV doppler examinations may be performed in the sitting positions. Examination in the sitting position may be helpful in recognizing pre-steal and retrograde flows.

Keywords: *Carotid vertebral doppler, position, sit, steal syndrome, supine, volume flow*

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Introduction

Carotid and vertebral (CV) Doppler ultrasonography (USG) is the primary diagnostic tool for the detection of extracranial atherosclerotic disease and the measurement of posterior fossa blood flow volume. It is a widely used non-invasive method to detect CV artery stenosis or occlusions, which are considered as the major reasons for cerebrovascular disease. The examination is performed while the patient lies in the supine position. However, in daily practice, we occasionally encounter patients who are not able to lie down in the supine

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Address for correspondence: Dr. MA İkidağ, Department of Radiology, SANKO Hospital, Ali Fuat Cebesoy 45, Gaziantep, Turkey.
E-mail: mikidag@hotmail.com

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position for different reasons, such as kyphosis, severe dyspnea, or severe back pain. We aimed to compare the spectral measurements of CV arteries which are obtained in supine and sitting positions.

Material and Methods

This prospective, cross-sectional, and descriptive study was confirmed by our ethical committee (31.01.2019-15), and all patients who participated in the study signed an informed consent. The study was conducted in a tertiary hospital, between June 2019 and December 2020.

Patient selection

Patients referred to our department for CV Doppler USG were consecutively recruited. Patients that had serious clinical disorders such as poor neurological condition, acute cerebrovascular disease, acute myocardial infarction, with prior history of carotid endarterectomy, or who were unable to sit were excluded. There were three groups in our study. The first two groups were consistent of patients with suspected or known carotid atherosclerotic disease, while the third group had vertigo [Figure 1]. Fifty-three patients were recorded as the first group, to whom CV Doppler examination was initially performed while sitting, and another 52 patients were examined as the second group that initial measurements were done in the supine position. Also, another 83 patients with a complaint of vertigo were included in the third group, but only vertebral artery (VA) measurements were compared.

Doppler examination

All patients underwent Doppler ultrasound examination with the aid of a Siemens Acuson S 2000 device (Siemens, Erlangen, Germany), equipped with a linear 9L4 probe. The vendor's preset CV program was used. Patients in the first group initially sit on an examination couch leaning on a pillow, tilting their heads approximately 45° across the examination side. After grayscale evaluation, spectral measurements were obtained and recorded from right and left common carotid artery (CCA), internal carotid artery (ICA), and VA. Peak systolic velocity (PSV), end diastolic velocity (ED) from each vessel, ICA/CCA ratio, and volume flow of VAs were measured. At the end of the study, the patients were asked to lie down on their back, and after 5 min resting period, all measurements were repeated by another radiologist. In the second group, patients lied down on their back on an examination couch with a pillow under their back, tilting their head approximately 45° across the examination side. After grayscale evaluation, spectral measurements were obtained and recorded from right and left CCA, ICA, and VA; and PSV, ED, ICA/CCA ratio, and volume flow of VAs were measured. At the end of the study, the patients were asked to sit, and after 5 min resting period, all measurements were repeated by another radiologist. All patients in the third group underwent VA measurements in the sitting position at first, and after lying in the supine position and 5 min of resting period, routine CV Doppler examination was performed.

The Doppler examinations were performed by two radiologists who were experienced in carotid Doppler for at least 15 years.

After axial examination of the common carotid artery and carotid bulbus, the lateral and larger vessel beyond the bifurcation was accepted as ICA. When there was a doubt in discrimination of ICA and ECA, branching vessel beyond the bifurcation was accepted as ECA, since ICA has no branch in the cervical segment. Spectral measurements were obtained in sagittal planes, and doppler angle was kept between 45° and 60°. VA flow volume was automatically calculated by the device after we marked the PSV, EDV on the spectrum and measured the vessel diameter.

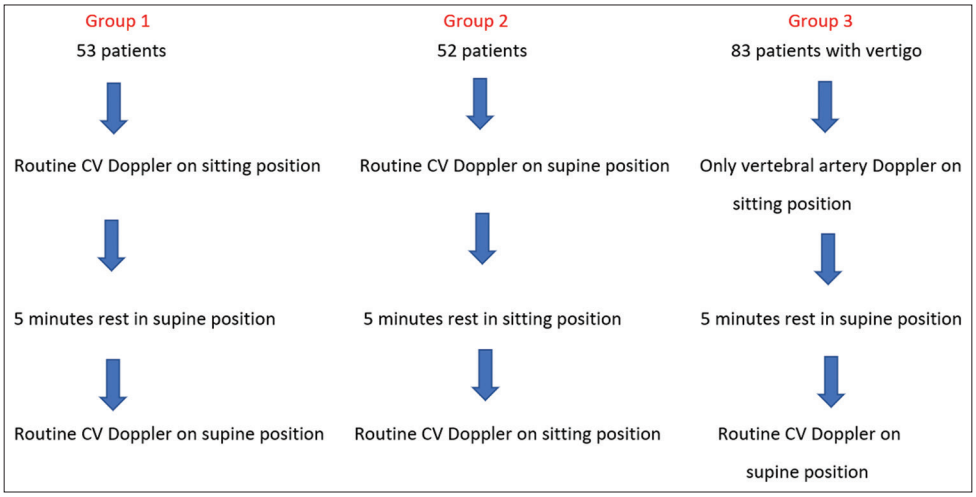

Figure 1: Recruited patients and data collection

Table 1: Overall results and comparison of three groups

	Group 1			Group 2			Group 3		
	Sit	Supine	*P*	Sit	Supine	*P*	Sit	Supine	*P*
Right CCA Systole	60.53±20.17	64.19±20.42	0.056	63.71±20.29	59.9±21.10	**0.032***	-	-	-
Right CCA Diastole	18.74±14.81	18.64±8.13	0.961	13.23±5.25	15.08±6.25	**0.019***	-	-	-
Right ICA Systole	58 (11-617)	66 (24-590)	0.758	77.15±32.53	76.25±34.55	0.710	-	-	-
Right ICA Diastole	20 (6-249)	20 (8-278)	**0.001***	21.10±10.65	23.23±11.31	0.075	-	-	-
Right ICA/CCA	1.07 (0.40-11.99)	1.1 (0.58-6.89)	0.105	1.25±0.54	1.30±0.51	0.237	-	-	-
Right VERT Systole	45.26±14.18	45.40±14.91	0.940	45.63±19.39	44.21±19.13	0.371	43.35±12.91	45.49±13.10	0.067
Right VERT Diastole	12.79±5.1	14.74±6.21	**0.001***	13.12±8.31	13.46±7.78	0.731	11.77±4.87	13.75±4.79	**<0.001***
Right VERT flow	61.40±38.27	62.34±32.02	0.820	63.12±37.95	65.69±41.13	0.452	64.17±31.96	67.18±31.26	0.064
Left CCA Systole	62.81±22.22	65.13±20.94	0.376	60.5 (26-388)	59.5 (11-387)	0.215	-	-	-
Left CCA Diastole	15.38±6.33	18.34±7.07	**0.002***	14.77±8.98	17.48±11.61	0.014*	-	-	-
Left ICA Systole	66 (32-408)	68 (31-308)	0.333	73.5 (32-510)	69.5 (26-533)	0.559	-	-	-
Left ICA Diastole	20 (6-143)	21 (7-157)	0.131	18.5 (9-223)	20 (6-242)	0.883	-	-	-
Left ICA/CCA	1.1 (0.53 (5.34)	1.0 (0.55-7.55)	0.563	1.12 (0.16-12.23)	1.1 (0.38-19.20)	0.625	-	-	-
Left VERT Systole	49.81±22.85	50.04±19.72	0.920	52.46±23.87	52.13±21.36	0.858	48.59±12.88	48.69±12.30	0.923
Left VERT Diastole	14.81±8.68	17.45±9.12	**0.002***	15.02±7.26	16.17±6.55	0.058	13.98±5.59	16.41±5.74	**<0.001***
Left VERT flow	81.94±43.50	83.37±40.40	0.669	88.20±39.25	98.84±42.19	0.165	87.76±35.31	87.82±38.48	**0.042***

Mean±Standard deviation; Median (Min-Max); *Statistically significant *P* values

Table 2: Kappa Analysis

	Group 1		Group 2		Group 3	
	Kappa	*P*	Kappa	*P*	Kappa	*P*
Right ICA sit/supine	0.92	**<0.001**	1.00	**<0.001**	-	-
Right VA sit/supine	0.58	**<0.001**	0.45	**<0.001**	0.59	**<0.001**
Left ICA sit/supine	0.90	**<0.001**	1.00	**<0.001**	-	-
Left VA sit/supine	0.60	**<0.001**	0.52	**<0.001**	0.59	**<0.001**
Total VA sit/supine	0.44	**<0.001**	0.40	**<0.001**	0.62	**<0.001**

The grading of carotid artery stenosis and occlusions were made as follows:

1: Normal ICA PSV <125 cm/s, ICA/CCA <2, ICA ED <40 cm/s
2: 50–69% stenosis ICA PSV 125–230 cm/s, ICA/CCA 2–4, ICA ED 40–100 cm/s
3: 70–99% stenosis ICA PSV >230 cm/s, ICA/CCA >4, ICA ED >100 cm/s
4: Occlusion.

Pre-occlusive stenosis that was characterized by slow flow accompanying severe stenosis (i.e., string sign) was graded in the third group.

According to VA flow volume, the results were grouped as follows:

1: Below 50 ml/s
2: Between 50 and 99 ml/s
3: Between 100 and 149 ml/s
4: Between 150 and 199 ml/s
5: Above 200 ml/s
6: Occlusion (no flow)
7: Pre-steal waveform
8: Reverse flow.

Statistical analyses

IBM Statistical Package for Social Sciences version 23 was used for analyzing data. Mean and standard deviations for continuous variables, frequency, and percentages for categorical variables were given as descriptive statistics. The normality of the data was

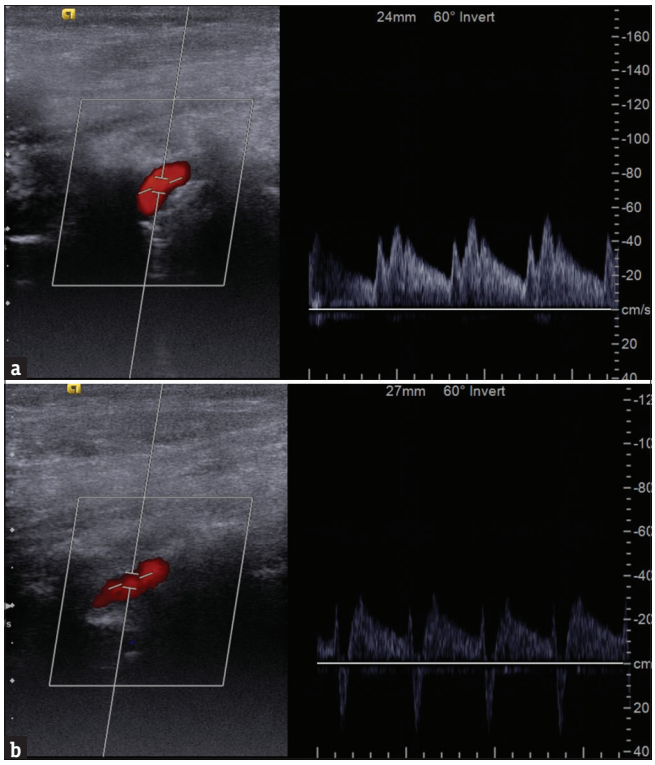

Figure 2: (a) Left VA Doppler spectrum of a 61 years old male in the supine position. (b) Left VA Doppler spectrum of the same patient in the sitting position. Note the early systolic retrograde flow

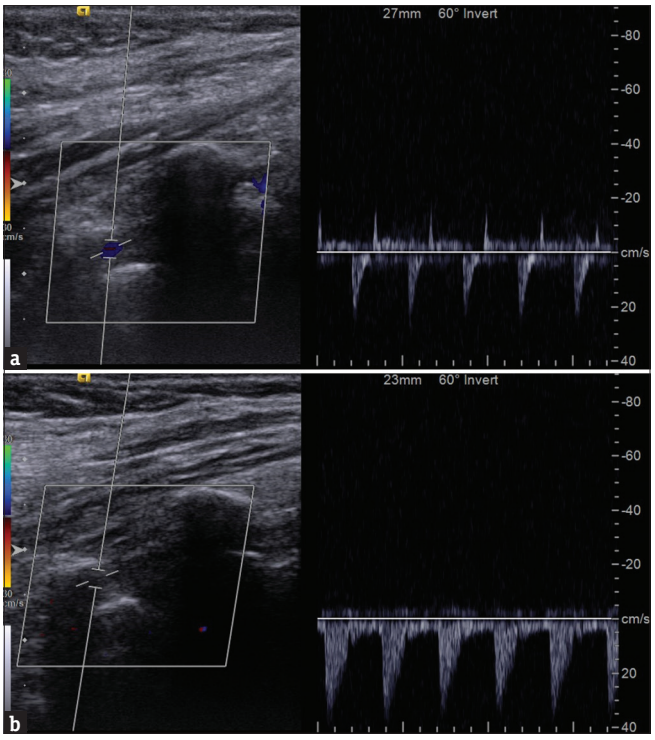

Figure 3: (a) Left VA Doppler spectrum of a 67 years old male in the supine position shows early systolic retrograde and subsequent weak antegrade flow. (b) Left VA Doppler spectrum of the same patient in the sitting position. Waveform of VA changed, both systolic and diastolic retrograde flow is seen

assessed by Kolmogorov–Smirnov test. Paired t-test was used for comparison of supine and sitting position parameters. Percent changes between supine and sitting positions were calculated in each group, medians and percentiles were calculated. $P < 0.05$ was considered as statistically significant. Also, percent changes between sitting and supine positions were calculated. Kappa values were obtained to assess agreement between sitting and supine positions. $P < 0.05$ were considered statistically significant.

Results

There were 53 patients (28 male, 25 female, 23–84 years, mean 61,13 years) in the first group, 52 patients (34 male, 18 female, 22–81 years, mean 60,67 years) in the second group, and 83 patients (46 male, 37 female, 22–86 years, mean 55,61 years) in the third group.

In the first group, while there was a statistically significant difference between sitting and supine positions in terms of right ICA diastolic, right and left VA diastolic, and left CCA diastolic velocities ($P < 0.05$), no difference was observed in terms of other parameters ($P > 0.05$). When the median value of the percent change in the lying position compared to the sitting position is examined, it was observed that there was a change of 16.67% (−4.09;43.65) in the right ICA diastolic, 10.00% (−3.13;36.93) in the right vertebral diastolic, 25.00% (−7.18;52.78) in the left CCA diastolic, and 11.11% (−2.00;34.62) in the left vertebral diastolic velocities [Table 1].

In the second group, while there was a statistically significant difference in sitting and supine positions in terms of right CCA systolic, right CCA diastolic, and left CCA diastolic velocities ($P < 0.05$), no difference was found in other parameters ($P > 0.05$). When the median value of the percent change in the lying position compared to the sitting position is examined, a change of − 2.69% (−19.09;8.90) in right CCA systolic, 13.96% (−10.61;53.41) in right CCA diastolic, and 19.09% (−9.54;65.63) in left CCA diastolic velocities were observed [Table 1].

In the third group, while there was a statistically significant difference in sitting and supine positions in terms of right and left VA diastolic velocities, left VA volume flow, and total VA volume flow ($P < 0.05$), no difference was observed in terms of other parameters ($P > 0.05$). When the median value of the percent change in the lying position compared to the sitting position is examined, it was observed that there was a change of 12.50% (0.00;42.86) in the right vertebral diastolic velocities, 14.29% (0.00;40.00) in the

left VA diastolic velocities, 4.00% (−6.67;20.52) in the left VA volume flow, and 3.70% (−1.73;15.79) in the total VA volume flow [Table 1].

As a result of Kappa analyses, a strong correlation was detected between supine and sitting positions in groups 1 and 2, regarding right and left ICA stenoses. In groups 1, 2, and 3 right and left arterial blood flow measurements, there was a medium correlation between supine and sitting positions. In total vertebral flow measurement, correlations between supine and sitting positions were medium in group 1, weak in group 2, and decent in group 3 [Table 2].

Alterations in waveforms were noted in three patients' unilateral VAs, in supine and sitting positions. In a case where the normal flow was observed in the supine position, pre-steal flow forms appeared in the sitting position [Figure 2a and b]. In a patient in whom pre-steal waveforms were detected in the supine position, retrograde flow consistent with steal syndrome was observed in the sitting position [Figure 3a and b]. In a patient with early diastolic notch in the supine position, the notch became prominent in the sitting position and early diastolic mild backflows were observed.

Discussion

Our results suggest that CV artery doppler examinations may be performed in the sitting positions.

CV artery Doppler USG is a rapid, non-invasive, and easily accessible test that shows cerebral blood flow. A supine patient position is recommended during the examination.[1] However, in daily practice, ideal conditions may not be provided for every patient. In our study, the lack of difference between position and systolic flows in all three groups (except for group 2 right CCA) was thought to be due to cerebral autoregulation. Many factors affect cerebral blood flow, such as blood pressure, arterial blood gases, and the autonomic nervous system.[2] It is known that blood flow is kept as constant as possible through cerebral autoregulation.[3] Although there are many studies evaluating cerebral blood flow in the supine and sitting positions, it is still unclear whether body posture affects the results. While some studies show that cerebral blood flow does not change with posture,[4-7] some studies show that cerebral blood flow is better when lying down.[8,9] In their study Geinas *et al*.[7] showed that cerebral perfusion was well preserved during changes in posture, although there were significant changes in perfusion pressure with head-up and head-down tilt tests.

The lower measurement values of diastolic flow velocities in the sitting positions found in our study may be because of gravity. Normally, cerebral blood flow is greater in the supine position compared to lying, sitting, and standing upright.[8] While the brain constitutes 2% of the body weight, it receives about 15–20% of the cardiac output. While lying on back, gravity exerts an even effect at the level of the heart, feet, and head; sitting or standing up breaks the balance in arterial and venous pressures. In a healthy individual, the brain effectively minimizes the effect of gravity through a continuous negative intracranial pressure.[10] When the gravitational effect is minimized in space travel, the blood is redistributed to the upper parts of the body. After returning to earth, the astronauts experience symptoms such as facial pallor, cold sweat, nausea, and presyncope for a certain period since the effect of gravity is activated again.[11] A similar situation is observed in people who had to take long-term bed rest.[10]

While there was no difference in total vertebral flow with the position in groups 1 and 2, the lower measurement of flow in the sitting position in group 3 who referred with the complaint of vertigo suggested that people who may have problems in autoregulation mechanisms may be affected by the position of the body. VAs supply the medulla oblongata, where vasomotor, respiratory, and cardiac control centers are located. It is thought that the ICA and VAs are affected differently in orthostatic stress situations. It has been suggested that clinical conditions such as syncope or presyncope result from vertebrobasilar hypoperfusion.[12] In their study Sato *et al*.[8] found that while ICA blood flow decreases during orthostatic stress, VA blood flow is preserved, and they suggested that cerebral autoregulation may be primarily involved because VAs provide blood flow to parts of vital functions. In a study investigating the changes in VA blood flow due to different head positions and cervical maneuvers, it was found that head positions did not cause significant changes in any of the hemodynamic parameters.[13] In addition, since the total vertebral output is found to be lower in the sitting position, it may be useful to add this difference to the result and indicate it in the evaluation.

In our study, it was observed that the detection of carotid stenosis was not significantly affected by the position. Carotid Doppler USG results performed in the sitting position can be considered reliable. As far as we know, there has not been a study in the literature on the position-dependent detection of stenoses. In a study conducted by Sands *et al*.[14] in the UK in 2020, they examined the relationship of head position with systemic and cerebral hemodynamic parameters in healthy controls and acute ischemic stroke patients. They detected cerebral blood flow velocity and mean arterial blood pressure better in the supine position.

VA flow measurements appear to be affected by position. VA waveforms were changed in supine and sitting positions in three of our cases. Examination in the sitting position may be helpful in recognizing pre-steal and retrograde flows. However, more work is needed on this subject.

The main limitation of the study is that we did not include critically ill patients in order not to prolong examination time. The results of this patient group may change the results, thus further studies including these patients would be beneficial.

In conclusion, the results can be evaluated as reliable in patients who undergo carotid artery Doppler USG in the sitting position. In the evaluation of VA flow, it may be useful to measure both sitting and lying positions. Shedding light on the effect of head position on cerebral blood flow is important not only in clinical use but also in understanding the underlying effects of cerebral autoregulation disorder.

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Conflicts of interest

There are no conflicts of interest.

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