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RESPONSE OF VERTEBRAL ARTERY BLOOD FLOW TO LASER IN ELDERLY WITH CERVICAL SPONDYLOSIS

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ABSTRACT

Background: This study targeted at finding out the response of the vertebral artery blood flow to Low-Level Laser Therapy (LLLT) in elderly with cervical spondylosis.

Methods: Research involved forty patients, both men, and women, whose ages between 60 and 75 years, diagnosed as chronic cervical spondylosis associated with vertigo. Subjects were randomly assigned to two equivalent groups. Group (1), Study Group, received low-level laser therapy (LLLT) with a wavelength of 830 nm and power of 200 mW on vertebral artery bilaterally. Group (2), the control group, received only sham laser (placebo). Both groups received three sessions per week for two months. Blood flow in both vertebral arteries was estimated by measuring Resistivity Index using ultrasound Doppler, and vertigo was assessed by visual vertigo analogue scale. The assessment was done pre and post-treatment.

Results: The outcomes of this study revealed highly significant difference between G1 and G2 in post-treatment values of resistivity index of both left and right vertebral arteries ($p=0.0008$ & 0.0002 respectively) as well as in visual vertigo analogue scale ($p=0.0001$), while comparing pretreatment values showed no significant differences between G1 and G2 ($p=0.329, 0.3795$ & 0.2518 respectively). In study group (G1), there was a significant decrease in resistivity index of both left and right vertebral arteries, as well as significant decrease in vertigo. Percentages of improvement were ($\downarrow 12.28\%$), ($\downarrow 13.98\%$) and ($\downarrow 64.24\%$) respectively, which means enhancement of blood flow through vertebral arteries. While (G2) showed a non-significant decrease in resistivity index of the left vertebral artery ($\downarrow 3.96\%$), right vertebral artery ($\downarrow 2.87\%$), and vertigo ($\downarrow 10.22\%$).

Conclusion: LLLT with parameters used in this study, improved blood flow through vertebral artery bilaterally and alleviated vertigo in elderly with cervical spondylosis.

Keywords: Low-level laser therapy; vertebral artery; resistivity index; vertigo; cervical spondylosis; elderly.

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INTRODUCTION

Cervical spondylosis (CS) can be referred to as the most prevalent degenerative disorders of the spine. It is of progressive nature that's overwhelmingly occurs naturally by aging. It is prescribed as a secondary disease to disc degeneration characterized by vertebral osteophytosis. It may be caused by osteophyte formations most commonly happening with progressive degeneration of cervical spine segment [1].

Compression on vertebral artery (VA) is caused by the influence of cervical osteophytes. Hence, occlusion takes place during head rotation to the same or opposite side [2].

Doppler ultrasound (US) is an assured method used to assess extracranial parts of vertebral arteries and carotids especially in patients suspected to have or suffering from any cerebrovascular diseases. It is applied in preoperative assessment as well as in screening [3].

Vertigo manifested in patients with CS is of specific high importance. In a study by *Olszewski et al. (2006)*[4], it demonstrated that vertigo existed among 50% of patients suffering from CS, while another study by *Colledge et al. (1996)* [5] stated that CS was the main cause of dizziness in 65% of geriatric patients.

Low-level laser therapy (LLLT) has picked up as of late prevalence in the treatment of blood vessel impediment specifically in arteries. LLLT of power under 500 mW is capable of inducing effects in biological tissues that are not thermal. The natural impacts of laser irradiation are seen at the level of the cell. They are believed to improve cellular membrane stability, increment transport intracellularly as well as discharging of endorphins and numerous different cytokines. Laser stimulation of the area of therapy leads to blood vessels dilatation. Moreover, it results in expanded blood stream volume. Means of vasodilator reflex presumably induces this expansion through CNS [6].

A study by *Mohamed (2005)* [7] listed LLL as a valuable therapy to improve vasodilatation, and additionally microvasculature augmentation. Likewise, it is believed to boost oxygenation in tissues [7]. Irradiation with LLLT of 830 nm wavelength and 100 mW power is found out to be a strongly effective strategy in the treatment of patients experiencing vertebrobasilar insufficiency (VBI).

Ten days of LLLT prompt a better change in patients' balance and overall stability, alongside marked attenuation of VBI symptoms. This could be ascribed to upgraded blood perfusion and enhancement of O₂ levels in brain tissue [8].

It is clear that degenerative CS in elderly is commonly associated with vertigo, headache and dizziness due to partial occlusion of the VA caused by osteophytes thus leading to a reduction in blood supply to brainstem, cerebellum and the posterior portions of the cerebrum.

However, there weren't enough studies done to make use of the previous findings in the management of VA occlusion and VBI in geriatric patients with cervical spondylosis.

Hence, this controlled randomized study came as a trial to detect the impact of LLLT on VA blood flow in elderly patients complaining from CS. It is of valuable benefit for medical service organization and increases the body of

knowledge of physical therapists for helping geriatric suffering from VBI associated with CS.

METHODS

I-Subjects:

The research involved forty patients participated in this study. Subjects are of both sexes (17 men and 23 women), with ages from 60 to 75 years. They were randomly picked from the outpatient clinic of Elmatareya and Ahmed Maher Teaching Hospitals. All were diagnosed as chronic CS associated with vertigo with/without other symptoms of VBI which might include tinnitus, blurring of vision, balance impairment and/or headache. The study was conducted from June 2015 to May 2017.

Patients were randomly assigned to two equivalent groups. The study group, the Group (1), received (LLLT) low-level laser therapy (irradiation) on the vertebral artery bilaterally while group (2) received only sham laser (irradiation turned off) thus serving as the (control group).

Inclusive criteria of the study:

Patients contributed in this study were both genders. Their ages ranged from 60 to 75 years, and of normal Body Mass Index (BMI) (from 18.5 – 24.9 kg/m²). They were all diagnosed as moderate chronic cervical spondylosis of more than five years, suffering from vertigo with/without other symptoms of VBI (tinnitus, blurring of vision, balance impairment and/or Headache). All subjects contributed in this trial were medically stable and didn't suffer from any other diseases which might affect trial results. They didn't receive physical therapy sessions or any other therapeutic method of treatment (including all sources of heat) or stopped these treatments six months ago.

Exclusive criteria:

Patients were excluded if they had one or more of the following criteria: Overweight or obese subjects (BMI equal to or above 25 kg/m²), patients who had undergone any previous cervical surgery, those with CS secondary to trauma or with metal implants, and also subjects with CNS dysfunction. Patients with a history of cardiovascular, middle and inner ear problems, vestibular neuritis, central canal stenosis, or previous cervical structural instability were also excluded. Those being treated with analgesics, vasodilators, antihypertensives or any other drugs which might cause misleading results were also eliminated. Hypo, hypertensives, diabetics, heavy smokers & alcoholics were estranged.

II- Methods:

1) Tools & Instruments:

(A) Evaluation tools:

1. Ordinary weight and height scale:

An ordinary weight scale was used in this study to determine each patient's weight and height.

2. Extracranial Ultrasound Duplex:

Extracranial Ultrasound (US) Duplex (Type: Samsung RS80A Doppler Ultrasound system, made in South Korea) was used for recording VA blood flow pre and

post the treatment program.

3. Visual Vertigo Analogue Scale (VVAS):

A scale that indicates the quantity of dizziness the patient experienced in certain movements by pointing the scales. VVAS is represented from zero to 10, where “zero” expresses no dizziness, while “10” expresses maximum dizziness [9].

(B) Treatment instruments:

1) Low-Level Laser Therapy:

The “BTL 5110” Laser Therapy Device (made in Czech Republic, EU) was used in this study with 830 nm wavelength and 200 mW power. The manufacturer routinely performed device calibration.

2) Procedures:

A- Evaluating procedures:

1. Measuring weight and height

Weight and height of each patient were measured using an ordinary weight scale. Every subject's Body Mass Index (BMI) was computed by the equation in which the weight (measured in kilograms) is divided by the height (calculated in meter square) [10].
$$BMI = \frac{\text{weight (kg)}}{\text{height (m}^2\text{)}}$$

2. Extracranial Ultrasound Duplex

The Vertebral Artery (VA) blood flow was measured (for both groups) by using the US Duplex, and the Resistivity Index (RI) was recorded before starting the therapy and after two months (24 sessions). Each patient had to assume the supine position. Whereas, head rotated to the left side for the recording of right (Rt) VA and to the right side for the recording of left (Lt) VA.

3. Visual Vertigo Analogue Scale (VVAS)

Every patient was asked to determine the degree of dizziness which he/she experienced in this horizontal line which begins from zero (no dizziness) to 10 (most severe dizziness). The assessment was done before starting the therapy and after 24 sessions.

B: Treatment procedures:

1. Study Group (G1)

G1 was composed of twenty (20) patients, (9 men and 11 women), who received LLL therapy (irradiation) on both vertebral arteries as follows:

Patients assumed the sitting position and LLLT were applied along the course of the vertebral artery bilaterally (8 points on each side), where every point was irradiated using the following parameters:

- Intensity: 200 mW.
- Wavelength: 830 nm.
- Duration: 1 minute to every point along the course of the Vertebral Artery in each session. Sessions repeated three times/week.

2. Control Group (G2)

G2 was composed of twenty (20) patients, (8 men and

12 women), serving as the control group, who received only sham laser (laser irradiation turned off)

C: Statistical analysis:

SPSS program version number 23 was used to perform the statistical analysis of this trial. Significance level adjusted at ($p < 0.05$). The following statistical analysis was done.

• Descriptive analysis:

- The mean was used as an average describing the central tendency of observations.
- The standard deviation was utilized to measure scattering of results around the mean.

• Inferential statistical analysis (Comparison of means):

- Paired t-test was employed to statistically compare variables and decide if they differ significantly within the same group. On the other hand, implementation of unpaired t-test determined the significance of measured variables between G1 and G2.

RESULTS

The age of patients shared in the study falls between 60 to 70. Mean age (\pm SD) was 65.45 ± 4.43 for the study group (G1), and 65.95 ± 4.058 for the control group (G2). No significant difference detected in age ranges between G1 & G2, as t score = 0.3722, p -value = 0.7118. G1 was formed of 9 men and 11 women, while G2 was constituted of 8 men and 12 women.

All patients involved in this study were of normal Body Mass Index (BMI), ranged from (19.5 to 25). Mean BMI of G1 and G2 was (23.062 ± 1.767) and (22.8205 ± 1.762) respectively. The unpaired t-test revealed no significant difference concerning BMI between both groups where t score = 0.4337, p -value = 0.6670.

Statistically, there weren't any significant differences in pretreatment values between both groups. Post-treatment results in (G1) showed a significant difference in the measured variables than pre-treatment values, while there was no significance between pre and post-treatment results in (G2). Meanwhile, comparing post-treatment results between groups (G1 and G2) revealed highly significant difference as shown below.

The obtained data were analyzed, expressed and summarized as follows:

1: Comparison between Lt VA RI of study and control groups pre and post-treatment.

Before the intervention, there wasn't any significant difference found in Lt VA RI mean value of G1 when being compared to that of G2 being 0.696 ± 0.0846 and 0.67 ± 0.0817 respectively ($p = 0.3290$).

The paired t-test revealed a highly significant decrease in RI of Lt VA in G1 after laser therapy compared to that before treatment, where mean values equal 0.6105 ± 0.07904 and 0.696 ± 0.0846 respectively ($p = 0.0002$), and percentage of improvement equal to ($\downarrow 12.28\%$). While in G2, there wasn't any significant difference in RI pre and post-treatment ($p = 0.2024$), where mean values equal 0.67

± 0.0817 and 0.698 ± 0.0726 respectively, and percentage of improvement equal to ($\downarrow 3.96\%$) (Table 1 and Graph 1)

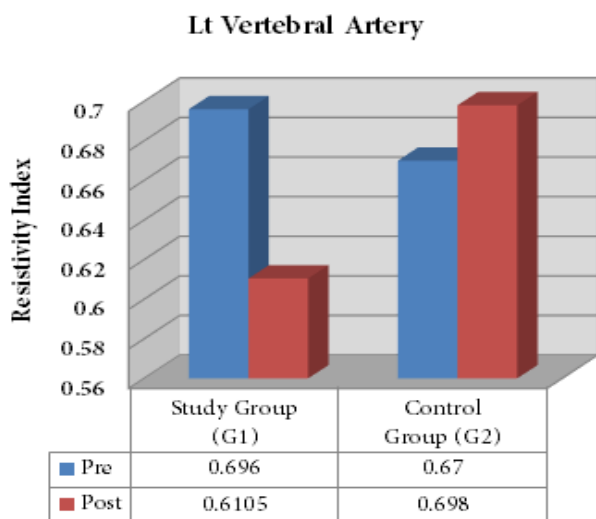
Table 1: Comparison between mean (\pm SD) of left vertebral artery Resistivity Index of study and control groups pre and post-treatment

Left Vertebral Artery Resistivity Index	Study Group (G1) (n=20). Mean (\pm SD)	Control Group (G2) (n=20). Mean (\pm SD)	Comparison (between groups) G1/G2	
			t	p
Pre treatment	0.696 \pm 0.0846	0.67 \pm 0.0817	0.9889	0.3290*
Post treatment	0.6105 \pm 0.07904	0.698 \pm 0.0726	3.646	0.0008**
% of improvement	\downarrow 12.28%	\downarrow 3.96%		
Comparison (within group) pre/post	t	4.646	1.320	
	P	0.0002**	0.2024*	

** Highly Significant

* Not Significant

Graph 1: Mean values of left vertebral artery Resistivity Index pre and post treatment in both study and control groups



By using a unpaired t-test to compare RI mean values post-treatment between G1 and G2, there was a significant difference where ($p=0.0008$).

2: Comparison between Rt VA RI of study and control groups before & after treatment.

Before the intervention, there wasn't any significant difference upon comparing Rt VA RI mean value of G1 to that of G2 being 0.6865 ± 0.0853 and 0.663 ± 0.0818 respectively ($p=0.3795$).

The paired t-test revealed a highly significant decrease in RI of Rt VA in G1 post laser irradiation in comparison to that pretreatment, where mean records equal 0.5905 ± 0.0624 and 0.6865 ± 0.0853 respectively ($p=0.0005$), and percentage of improvement equal to ($\downarrow 13.98\%$). While in G2, there wasn't any significant difference in RI pre and post-treatment ($p=0.4427$), where mean values equal 0.663 ± 0.0818 and 0.682 ± 0.0752 respectively and percentage of improvement equal to ($\downarrow 2.87\%$). (Table 2 and Graph 2)

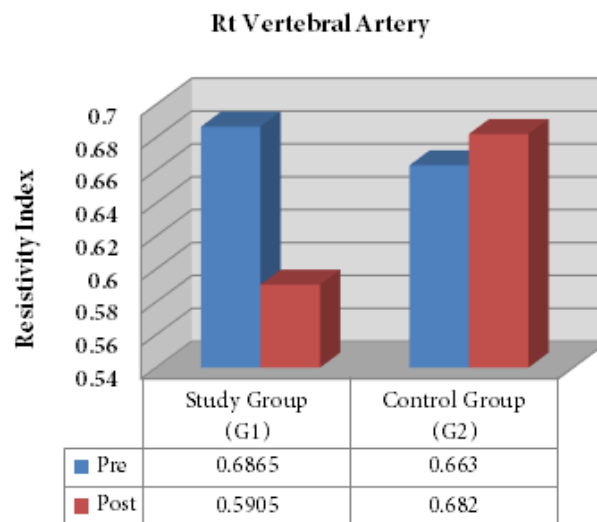
Table 2: Comparison between mean (\pm SD) of right vertebral artery Resistivity Index of study and control groups pre and post- treatment

Right Vertebral Artery Resistivity Index	Study Group (G1) (n=20). Mean (\pm SD)	Control Group (G2) (n=20). Mean (\pm SD)	Comparison (between groups) G1/G2	
			t	p
Pre treatment	0.6865 \pm 0.0853	0.663 \pm 0.0818	0.8891	0.3795*
Post treatment	0.5905 \pm 0.0624	0.682 \pm 0.0752	4.188	0.0002**
% of improvement	\downarrow 13.98%	\downarrow 2.87%		
Comparison (within group) pre/post	t	4.209	0.7840	
	P	0.0005**	0.4427*	

** Highly Significant

* Not Significant

Graph2: Mean values of Right vertebral artery Resistivity Index pre and post treatment in both study and control groups



Meanwhile, highly significant difference appeared by using unpaired t-test to compare RI mean values post-treatment between G1 & G2, where ($p = 0.0002$).

3: Comparison between Visual Vertigo Analogue Scale (VVAS) of study and control groups before & after treatment.

Before the intervention, no significant difference detected when comparing G1 VVAS mean score to that of G2 being 7.55 ± 1.905 and 6.85 ± 1.899 respectively ($p=0.2518$).

The paired t-test revealed a highly significant decrease in VVAS in G1 after laser irradiation compared to that before treatment, where mean values equal 2.7 ± 2.203 and 7.55 ± 1.905 respectively ($p=0.0001$), and percentage of improvement equal to ($\downarrow 64.24\%$). While in G2, there wasn't any significant difference in RI pre and post-treatment ($p=0.2284$), where mean values equal 6.85 ± 1.899 and 6.15 ± 2.231 respectively, and percentage of improvement equal to ($\downarrow 10.22\%$). (Table 3 and Graph 3)

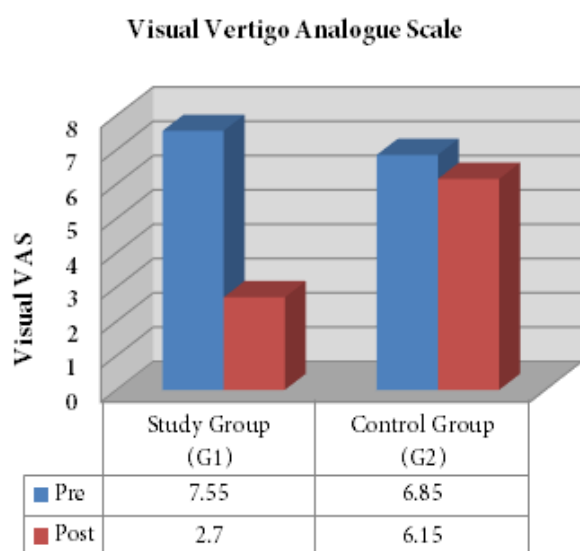
Table 3: Comparison between mean (\pm SD) of Visual Vertigo Analogue Scale of study and control groups pre and post- treatment

Visual Vertigo Analogue Scale (VVAS)	Study Group (G1) (n=20). Mean (\pm SD)	Control Group (G2) (n=20). Mean (\pm SD)	Comparison (between groups) G1/G2	
			t	p
Pre treatment	7.55 \pm 1.905	6.85 \pm 1.899	1.164	0.2518*
Post treatment	2.7 \pm 2.203	6.15 \pm 2.231	4.921	0.0001**
% of improvement	\downarrow 64.24%	\downarrow 10.22%		
Comparison (within group) pre/post	t	6.395	1.245	
	P	0.0001**	0.2284*	

** Highly Significant

* Not Significant

Graph 3: Mean values of Visual Vertigo Analogue Scale pre and post treatment in both study and control groups



By using unpaired t-test to compare VVAS mean values post-treatment between G1 & G2, the highly significant difference was revealed, where ($p=0.0001$).

DISCUSSION

This current trial results declared highly significant difference among study and control groups post-treatment in resistivity index of both left and right vertebral arteries ($p=0.0008$ and 0.0002 respectively) as well as in visual vertigo scale ($p=0.0001$).

This indicated that LLLT could be of great value in the management of vertebrobasilar insufficiency (VBI) accompanying cervical spondylosis in elderly. Resistivity index of vertebral arteries, as well as vertigo, decreased effectively in response to LLLT.

The outcomes of this present study came in agreement with *Lukowicz et al.(2011)[8]*, where global stability, as well as VBI symptoms and balance, improved significantly after LLL irradiation to vertebral arteries bilateral. They stimulated VA in 5 points for ten successive days and used same wavelength (830 nm) but a lower power (100 mW), and

they explained their results suggesting that Laser caused more blood perfusion and an elevation of oxygen level in the brain. This was proven in our trial by the significant decrease in resistivity index of VA; however, we used different irradiation protocol and higher power.

As far as we know, no other published studies explored the direct effect of laser on resistivity index of vertebral artery blood flow especially in the presence of age-related cervical spondylosis.

Though this scarcity of literature, yet various researchers – as discussed below - explored the effect of LLLT on blood flow of various arteries some of which was in healthy subjects and others on animals (in-vivo).

In the study by *Makihara and Masumi (2008) [6]*, the diameter of superficial temporal artery as well as blood flow volume increased significantly on irradiated side 10 minutes after ceasing irradiation with respect to that before exposure.

In agreement with the results of this trial, *Schaffer et al. (2000) [11]* used MRI imaging as an assessment and found improvement in blood flow after applying LLL (780 nm) to the planta pedis artery of healthy subjects without any increase in tissue temperature.

Teggi et al. (2008) [12] utilized LLL as a remedy for patients suffering from Meniere's disease (MD). They targeted the inner ear and found that LLLT leads to significant decrease in vertigo spells, although their outcomes have demonstrated that it possesses slower action, but they attributed this to dose-dependent as they only used a wavelength of only 650 nm and very low power (5mW). However, they explained the therapeutic results due to increased blood flow.

On the other hand, some scientists successfully used LLLT in the treatment of many vascular conditions. Patients with Raynaud's phenomenon were treated by *Hirschl et al.(2004)¹³* who found that LLL has a marked effect in preventing the vasospasm.

Results of this current trial also agree with the data obtained by *Tullberg et al.(2003 [14]* who exposed masseter muscle to (GaAlAs) gallium-aluminium-arsenide LLL to treat muscular pain. However, they found an increase in microcirculation.

Since it is widely proven and strongly accepted that infiltration depth of laser depends on its wavelength, further penetration occurs with longer wavelengths [15,16], so in the current study, we utilized LLLT with 830 nm wavelength which is characterized by its deeper penetration into tissues.

Improved circulation in response to treatment with LLL is believed to be one of the conceivable mechanisms concerning clinical efficacy of laser in management of pain, musculoskeletal disorders or wound healing. In spite of the fact that, the fundamental interaction techniques between various wavelengths and biological tissues are - until now - not fully comprehended, yet some authors did many examinations to study how LLL improves circulation locally. It has been confirmed to speed up collateral circulation and promote microcirculation.

Results of this present trial came in line with sequels of *Maegawa et al. (2000) [17]*; who studied the response of vascular smooth muscle cells (VSMCs) under the impact of 830 nm wavelength infrared laser. They concluded that laser irradiation could cause marked dilatation in vessels and expansion in the bloodstream of arterioles through a direct effect on VSMC as it reduced $[Ca^{2+}]$ ions in microvascular smooth muscles.

A systemic review conducted by *Hamblin (2008) [18]* demonstrated and proved the ability of light to have a great impact on the localized release of nitric oxide (NO) and lead to vasodilation through the effect of NO on cyclic guanosine monophosphate cGMP.

Findings of this current study are supported by *Mittermayr et al. (2007) [19]*. They explained the underlying mechanism through which LLL enhances blood flow. They proved that laser could increase blood circulation locally without affecting the systemic circulation through its effect on NO. Red blood cells (RBCs) naturally possess (NO) sources that discharge NO when each RBC goes under laser source consequently becoming subjected to convenient photo energy wavelength. This NO release is exceptionally local and not being evident in unrelated body areas. Vasodilation caused by NO is attributed to the influence of guanylate cyclase (GC) enzyme that phosphorylates myosin by forming (cGMP) furthermore relaxing VSMCs.

CONCLUSION

Low-level laser irradiation with 830 nm wavelength and 200 mW power when applied on course of both vertebral arteries three sessions per week for two months, results in marked increase in blood flow and consequently decrease in vertigo in elderly suffering from cervical spondylosis.

Abbreviations or symbols:

BMI: Body Mass Index.

Ca: Calcium.

cGMP: cyclic guanosine mono phosphate.

CNS: Central Nervous System.

CS: Cervical Spondylosis.

EU: European Union.

G1: Group (1), study group.

G2: Group (2), Control group.

GC: guanylate cyclase.

Kg/m²: Kilograms per meter square.

LLL: Low-Level Laser.

LLLT: Low-Level Laser Therapy.

Lt: Left.

MRI: Magnetic Resonance Imaging.

mW: milliwatts.

nm: Nanometers.

NO: Nitric Oxide.

RBC: Red Blood Cell.

RI: Resistivity Index.

Rt: Right.

US: Ultrasound.

VA: Vertebral Artery.

VBI: Vertebro Basilar Insufficiency.

VSMCs: Vascular Smooth Muscle Cells.

VVAS: Visual Vertigo Analogue Scale.

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