4-2016

Cerebrovascular Reactivity Change with Increased Intracranial Pressure

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Background

Cerebrovascular reactivity (CVR) is a key factor in regulating blood flow into the brain, and a marker of vascular disease and cognitive decline. CVR reflects the ability of the cerebral arterioles and capillaries to dilate in response to an increase to the partial pressure of carbon dioxide. CVR can be quantified using transcranial Doppler (TCD) and CO2 as a vasodilatory stimulus. CO2 can be induced by acetozolamide, rebreathing exhaled gas, Inspired CO2 and Breath-holding. Breath-holding index (BHI) is a method developed by Markus[1] in 1992. Subjects are instructed to hold their breath, while TCD transducers measure blood cerebral flow velocities (CBFV) in the middle cerebral artery. BHI is the maximum percentage increase in blood velocity (while breath-holding) divided by the time which the maximum increase occurs. The purpose of this study was to test for a relationship between CVR and intracranial pressure (ICP).

Methods

In this study, intracranial pressure (ICP) was increased and cerebrovascular reactivity (CVR) was measured in 4 subjects (women over the age of 19) while they were lying on a tilt table. The tilt table, or inversion table, is an apparatus commonly used to relieve stress and strain on the back and increase blood circulation. The table was modified to be secured at increments of 15 degrees in order to change their ICP. Before entering the tilt table, the subject's middle cerebral artery (MCA) was found using Transcranial Doppler Ultrasonography. The transducer for the ultrasound was secured to the subject's head using a headband designed to maintain the signal while the subject is free to move. Once the MCA was located, the subject entered the tilt table and was secured at the first angle of positive 45 degrees. The subject's blood pressure and heart rate were taken using an automated blood pressure cuff. The subject then underwent a Breath Holding Test in order to measure CVR. For the Breath Holding Test procedure, the subject was asked to breathe normally for 30 seconds, hold their breath for 30 seconds, then breathe normally for 30 seconds, all while the blood flow velocity in their MCA was recorded. The procedure was repeated at six angles with the subject being allowed to rest between measurements. The angles at which the measurements were recorded were 45, 30, 15, 0, -15, and -30 degrees, positive angles being head up and negative angles being head down.

Results

Table 1. CVR at Various ICP Levels

Test	CVR1[1]	Mean Arterial Pressure
Subject 1 (45)	1.05	77.0
Subject 1 (30	1.70	85.3
Subject 1 (15)	1.42	79.6
Subject 1 (0)	1.58	89.6
Subject 1 (-15)	1.76	84.0
Subject 1 (-30)	1.08	84.3
Subject 2 (45)	1.72	83.3
Subject 2 (30)	1.10	84.7
Subject 2 (15)	1.80	84.7
Subject 2 (0)	1.38	84.7
Subject 2 (-15)	N/A*	N/A
Subject 2 (-30)	1.90	92.3
Subject 3 (45)	1.89	88.0
Subject 3 (30)	1.34	80.6
Subject 3 (15)	1.80	87.0
Subject 3 (0)	1.45	84.0
Subject 3 (-15)	1.10	84.0
Subject 3 (-30)	N/A	N/A
Subject 4 (45)	1.80	80.7
Subject 4 (30)	N/A	81.3
Subject 4 (15)	1.36	80.3
Subject 4 (0)	1.35	75.3
Subject 4 (-15)	1.41	78.3

*N/A indicates the inversion table would not lock at that angle or CVR values were outliers.

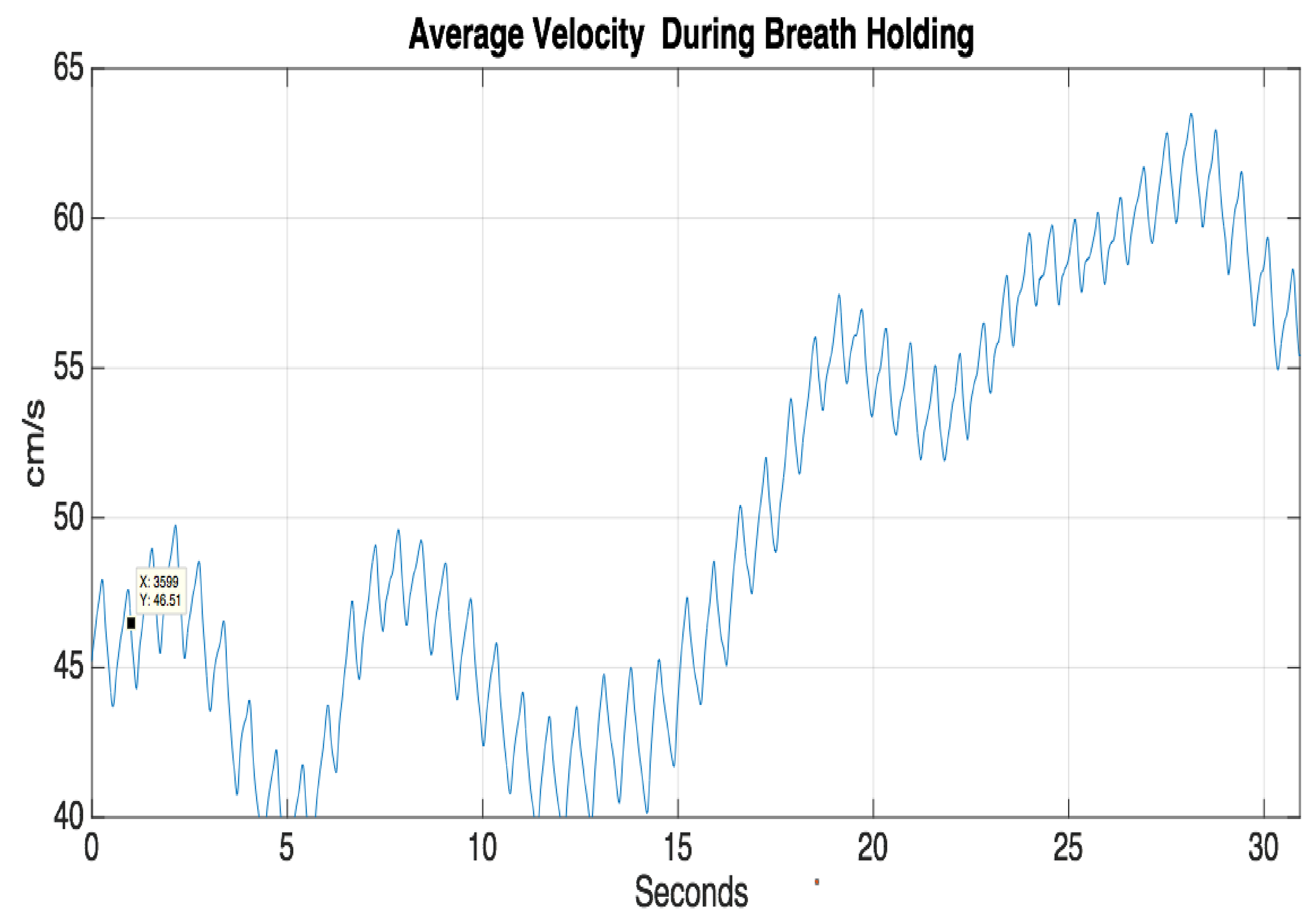

Figure 1. Average Velocity During Breath Holding for Subject 1

Angle	Average CVR
45	1.62
30	1.38
15	1.60
0	1.44
-15	1.42
-30	1.49

Table 2. Average CVR for Each Angle of the Inversion Table

CVR was calculated according to the following equation:

$$\frac{(V(mb)-V(mm))/(V(mb//))}{Time}$$

V(mb) is the mean blood flow velocity before the breath hold, and V(mm) is the mean blood flow velocity during the breath hold.
Mean arterial pressure was calculated using the systolic and diastolic pressures.

Discussion

In investigating the relationship between ICP and CVR, it appears that CVR did not consistently increase, decrease, or undergo no change between angles of the inversion table. To start the experiment, it was believed that ICP is, in fact, increasing, as the blood flow volume is increasing while going to negative angles in the tilt table. It is confirmed by the lack of consistent change in the mean arterial blood pressure and CVR as the angle vary that the ICP is increasing. A one way ANOVA test and multiple comparison with Tukey adjustments revealed that there was no significant difference between the CVR values. In regards to future research, more subjects are sought to solidify the data presented.

Acknowledgments

Marissa Nitz is recognized for her work developing and improving the head set used to record blood flow in the middle cerebral artery during a time consuming experiment. Max Twedt and Chase Pfeifer are recognized for their contributions to the NASA project, choosing the inversion table as a mode for increasing ICP and creating measurement techniques for the blood flow in and force on the ophthalmic artery.

References

1) Markus, H. S., & Harrison, M. J. (1992). Estimation of cerebrovascular reactivity using transcranial Doppler, including the use of breath-holding as the vasodilatory stimulus. Stroke; a Journal of Cerebral Circulation, 23(5), 668–673.