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B-Mode Doppler Ultrasound Blood Flow Velocity Measurements for the Determination of the Intima Media Thickness in the Human Carotid Artery

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Abstract
Excess mortality associated with cardiovascular diseases and stroke is linked to atherosclerosis which in turn, is related to the intima-media thickness (IMT). An increase in IMT in the common carotid artery (CCA) is therefore commonly used as a marker of atherosclerosis. The purpose of this study was to investigate the relationship between blood flow velocity and IMT in the CCA which is also an indicator of atherosclerosis in the carotid bifurcation. Fifty (50) apparently healthy volunteers (25 males and 25 females) whose ages ranged between 19 and 75 years were considered for carotid ultrasound scanning in Jos University Teaching Hospital (JUTH). IMT, Peak Systolic and End Diastolic blood velocities of the right and left Common Carotid Arteries (CCA) were measured by means of a Doppler Ultrasound Machine Type LOGIQ 5 EXPERT at 6MHz frequency with an insonation angle of 60^0 by a single trained sonologist. Quantitative variables were analyzed with the IBM SPSS. Results show that the Right Peak Systolic Velocity (RPSV) and the Left Peak Systolic Velocity (LPSV) of blood in the CCA correlate negatively with the Right Intima Media Thickness (RIMT). The LPSV of blood shows a negative correlation with the Left Intima Media thickness (LIMT) but the RPSV has no significant correlation with the LIMT. The RIMT and the LIMT show a strong positive correlation with age but no significant correlation with sex, Right End Diastolic Velocity (REDV) and Left End Diastolic Velocity (LEDV). The RPSV and REDV also show a negative and positive correlation with age respectively, but the LPSV and LEDV show no significant relationship with age. We therefore conclude that the RPSV and LPSV of blood in the CCA is correlated to the degree of atherosclerosis in the carotid bifurcations more than the REDV and LEDV. The degree of atherosclerosis increases with advancing in age because of the strong positive correlation between IMT and age.
Keywords: Intima-Media Thickness, Common Carotid Artery, Atherosclerosis.

1. Introduction

The Carotid Intima-Media Thickness (C-IMT), which reflects the burden of generalized atherosclerosis, is also associated with stroke (Kwon, *et al*., 2013). It has therefore been proposed as a risk factor that may be included in the algorithms for cardiovascular risk assessment as it provides an index of atherosclerosis in other vascular regions (Baldassarre *et al*., 2000). Measuring the thickness of the intima and media layers of the carotid artery wall is one way to assess the cardiovascular health of subjects. This simple, non-invasive and inexpensive procedure gives one another tool in the toolbox to further solve the diagnostic puzzle and helps one to accurately assess disease presence, risk of events, and progression of the disease before the subjects present any acute symptoms (CardioRisk Laboratories, 2015). The measurement of C-IMT is an accepted surrogate marker of atherosclerosis and has been extensively studied in numerous clinical trials (Hurst, *et al*., 2007; Vicenzini *et al*., 2007) beginning with the initial description by Pignoli *et al*. (1986) and currently accounts for the most extensive literature in the field of atherosclerosis imaging. However, criticism has been raised throughout the scientific community, based on the observations which indicated a weak correlation between C-IMT and coronary atherosclerosis (George, *et al*., 2013). Atherosclerosis is a condition in which fatty material deposits along the walls of arteries. This fatty material thickens, hardens (forms calcium deposits), and may eventually block the arteries. Atherosclerosis is a chronic inflammatory disease that has a silent course for a few decades before symptoms and atherothrombotic complications occur (Ross, 1999); in this stage the disease already has major and poorly reversible histopathological consequences. Early detection and treatment or prevention is therefore the best bet. Prevention requires an early identification of the individuals who are at a risk of developing cardiovascular disease but are clinically asymptomatic, so that intensive preventive measures may be instituted to arrest the progression of the disease. Atherosclerosis progression is associated with inflammatory changes from its early stages to the most advanced, accompanied by thrombotic events. The C-IMT measurement which directly correlates with pathology (Gamble *et al*., 1993), is indicative of the thickness of the arterial wall, and is precisely imaged using ultrasound technology. Thickening of the intima-media at any local site is generally considered to be an early marker of generalized atherosclerosis because such thickening has been associated with an unfavorable cardiovascular risk profile (Salonen and Salonen, 1990; Salonen *et al.,* 1988; Salonen and Salonen, 1991; Heiss *et al.,* 1991).

High-resolution ultrasound is commonly used to measure intima-media thickness (IMT) of the distal common carotid artery (CCA) below the carotid bifurcation (Person *et al.,* 1994). An increased IMT may predict future atherosclerotic morbidity, as it has for example been shown to correlate with the likelihood of acute coronary events (Salonen and Salonen, 1991). Moreover, in asymptomatic subjects a correlation has been shown between IMT and the presence of plaques in the femoral or carotid bifurcations and between IMT and number of carotid artery plaques (Veller *et al*., 1993; Person *et al.,* 1994). However, less is known regarding the relationship between IMT and the blood velocity in the carotid artery as there is the paucity of information relating the two. Parameters such as Peak Systolic Velocity (PSV) and End Diastolic Velocity (EDV) could be used to assess the hemodynamic effects of stenosis and could be relevant for management of decisions (Martinez *et al*., 2015). Such parameters may also be suitable for the measurement of the C-IMT. The normal intima-media thickness of common carotid artery as evaluated by B-mode ultrasound imaging is 0.74 ± 0.14 mm (Mohan *et al.,* 2000). Some studies also indicated that Carotid Artery IMT <0.8 mm is associated with normal healthy individuals, and a value of IMT at or above 1 mm is associated with atherosclerosis and a significantly increased cardiovascular disease (CVD) risk in any age group (Simon *et al.,* 2002). Kumar *et al*. (2009) and Howard *et al*. (1992) observed that Carotid Artery IMT of healthy controls were 0.73 mm and < 0.7 mm respectively.

There is still controversy regarding the IMT value of normal healthy people of different ethnicity, because IMT also depends on ethnicity which is a non-modifiable risk factor. Black ethnicity is related to greater mean and maximum IMT when compared to South Asians, even after adjusting for traditional cardiovascular risk factors (Bennett *et al.,* 2011). People of India and Bangladesh have similar type of food habits, life style and ethnicity which can be responsible for modification of the IMT. Majority of previous studies which were done to detect the IMT of normal healthy person, were performed in people of different parts of the world with different types of ethnicity, food habits and life style. For this reason, IMT value of normal healthy persons which was estimated by previous different studies may not be applicable on the people of India and Bangladesh. Our study was done to find out the relationship between blood velocity and IMT of apparently normal healthy people in Jos South local Government Area of Plateau State Nigeria and the relationship of non-modifiable risk factors such as age and sex with IMT.

2. Materials and Methods

The study included fifty (50) apparently normal healthy people (25 males and 25 females) having ages ranging between 19 to 75 years whose oral informed consent was obtained and the study was approved by the Jos University Teaching Hospital's Ethical Board. After taking consent, all subjects underwent a careful interview, clinical and radiological examination with an evaluation of patient history based on hospital and outpatients records. Modifiable traditional risk factors of atherosclerosis (Smoking, Hypercholesterolemia, Diabetes, and Hypertension) which may influence IMT value were examined carefully. The blood flow velocity in the carotid artery of each human subject was measured using the B-Mode of the Doppler ultrasound machine Type LOGIQ 5 EXPERT at 6MHz frequency with an insonation angle of 60^0 by a single trained sonologist. In the measurement, each subject was made to lie in a supine position on an examination bed with the neck and chest of the person exposed and a few drops of water soluble semi-liquid gel applied to the body surface around the neck. The probe was rotated on the right neck region until the carotid artery was seen as displayed on the monitor showing how the blood flows in the artery (see plate 1). The blood flow parameters such as the Right Peak Systolic Velocity and Right End Diastolic Velocity of the blood were automatically displayed on the screen as shown in plate 2. The same procedures were repeated on the left side of the neck for all the subjects.

Plate 1: Blood Flow in the Carotid Artery

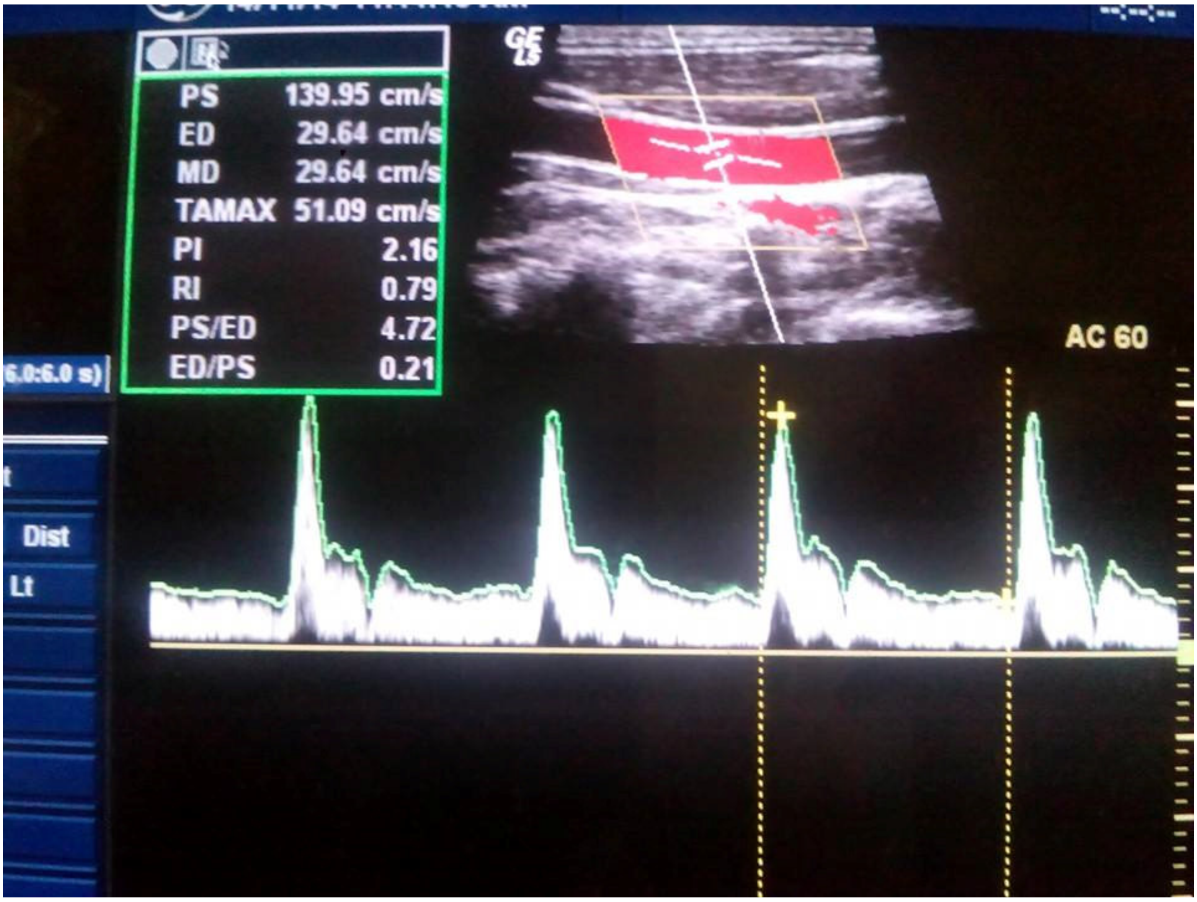

Plate 2: Monitor Display of Blood Flow Parameters

3. *Results and Discussion*

Data on the Peak Systolic Velocity (PSV), the End Diastolic Velocity (EDV) and the Intima Media Thickness (IMT) for the right and left Common Carotid Arteries (CCA) for the fifty subjects as measured with LOGIQ 5 EXPERT Ultrasound Machine using the technique of Doppler Ultrasound velocity measurement were read and recorded as shown in table 1. These results were analyzed using IBM SPSS (Statistical Packages for the Social Sciences) to establish existence or otherwise of correlations among sets of variables. Table 2 shows the correlations among the variables using the 2-tailed Pearson's correlation. The Pearson's correlation between any pair of variables with one asterisk shows that correlation is significant at the 0.05 level, while one with two asterisks shows that correlation is significant at the 0.01 level.

The LPSV is negatively correlated with the LIMT and RIMT (p value<0.05). However, it is positively correlated with LEDV (p value<0.05) and RPSV (p value<0.01). The RPSV is negatively correlated with age (p value<0.05) and RIMT (p value<0.01) but strongly correlated positively with REDV and LPSV (p value<0.01) but has no significant correlation with the LIMT. The IMTs of the right and left carotid arteries are each, strongly correlated positively with age (p value<0.01), but have no significant correlation with sex. The RPSV and the REDV are respectively correlated negatively and positively with age with a p value < 0.05, but the LPSV and LEDV have no significant correlation with age. The LIMT and RIMT are strongly correlated with each other (p value<0.01). On the whole, the LIMT and the RIMT of the carotid arteries could be determined from values of the peak systolic and end diastolic velocities of blood flow in the carotid arteries.

Results show a negative correlation between the Peak Systolic Velocity on the right and left of the Common Carotid Artery with the Intima-Media Thickness on the right carotid artery at the 0.01 and 0.05 significant levels respectively. These correlations give rise to the following regression equations as seen in figures 1 and 2.

$y_1 = 115 - 320x_1$ ……………………………………………………………1

$y_2 = 110 - 228x_1$ ……………………………………………………………..2

Where y_1, y_2 and x_1 are the RPSV, LPSV and RIMT respectively. These equations mean that the blood velocity on the right and left of the carotid artery decreases with an increase in the value of the IMT and vice versa.

4. Conclusion and recommendation

This study established a relationship between blood flow velocity in the carotid artery and intima-media thickness which is a surrogate marker of atherosclerosis which in turn is a risk factor of cardiovascular diseases and stroke. The blood flow velocity can therefore be used to detect cardiovascular disease in the subclinical phase. Several studies have shown that the carotid IMT is strongly associated with the cardiovascular risk factors (Stefan *et al.,* 1998). The mean LPSV and LEDV (90.02cm/s and 24.88cm/s) are higher than the mean RPSV and REDV (88.30cm/s and 23.85cm/s). Again, the mean RIMT (0.0652) is higher than the LIMT (0.0598). The implication of these is that the right carotid artery measurements is more reliable in the determination of atherosclerosis than that of the left carotid artery. It was observed that the Carotid Artery IMT of normal healthy persons (including all age groups) was 0.0725± 0.0175 cm which is nearly similar to other previous several studies. It is recommended that these studies should be carried out on different ethnic nationalities residing in different places.

Table 1: Common Carotid Artery (CCA)

S/N	AGE (yrs)	SEX	RIMT (cm)	RPSV cm/s	REDV cm/s	LIMT (cm)	LPSV cm/s	LEDV cm/s
01	19	F	0.05	109.62	24.13	0.04	83.42	24.13
02	22	F	0.08	109.62	19.99	0.03	105.48	24.13
03	23	F	0.05	91.69	25.51	0.04	1O8.24	2275
04	24	M	0.04	128.92	18.61	0.05	110.99	18.61
05	25	F	0.04	73.77	24.13	0.05	79.28	21.37
06	25	F	0.04	104.10	14.48	0.04	120.65	19.99
07	26	M	0.04	80.66	24.13	0.05	87.78	33.78
08	26	M	0.04	116.51	21.37	0.05	131.68	29.64
09	27	M	0.04	108.79	18.50	0.06	111.76	14.06
10	29	M	0.04	139.95	29.64	0.05	127.54	25.51
11	30	M	0.06	91.69	25.51	0.04	94.45	21.37
12	37	F	0.05	99.96	26.89	0.05	97.21	26.89
13	39	M	0.05	83.42	18.61	0.04	75.15	21.37
14	40	F	0.06	80.03	30.53	0.07	75.08	30.53
15	41	M	0.05	116.83	29.36	0.05	85.68	25.76
16	38	M	0.05	106.72	22.45	0.04	107.62	25.55
17	42	F	0.06	71.01	19.99	0.05	80.66	31.02
18	45	F	0.04	101.25	23.37	0.06	104.85	29.36
19	45	M	0.05	93.99	24.42	0.05	86.59	30.34
20	47	F	0.08	59.95	15.54	0.07	73.27	18.50
21	47	F	0.05	106.05	29.36	0.05	109.64	41.34
22	48	F	0.05	112.04	35.35	0.05	120.42	36.55
23	48	F	0.04	67.35	21.46	0.05	67.35	19.98
24	48	F	0.07	97.66	29.36	0.05	90.47	30.56
25	49	M	0.07	107.62	30.20	0.05	96.95	25.90
26	48	M	0.07	92.86	24.56	0.06	88.07	29.36
27	50	F	0.07	114.23	39.14	0.07	117.43	26.36
28	50	F	0.07	142.84	37.75	0.06	133.96	25.90
29	52	M	0.08	86.59	24.42	0.08	105.48	39.30
30	52	F	0.05	118.03	25.76	0.06	127.61	43.74
31	52	F	0.09	85.11	28.86	0.09	62.91	22.94
32	53	M	0.05	93.46	34.35	0.06	91.87	37.55
33	54	M	0.21	44.81	11.72	0.09	71.01	24.13
34	54	F	0.10	83.63	27.38	0.06	80.67	25.90
35	42	M	0.08	92.86	18.57	0.08	96.46	20.97
36	56	F	0.08	92.86	31.75	0.05	68.90	24.56
37	57	F	0.07	75.15	24.13	0.06	98.59	29.64
38	58	M	0.07	114.31	40.98	0.07	121.50	42.42
39	58	M	0.10	73.77	17.24	0.10	76.52	19.99
40	58	F	0.06	68.90	26.96	0.04	90.47	34.15
41	60	M	0.08	67.90	31.15	0.07	74.29	19.97
42	61	M	0.07	83.67	25.79	0.06	74.75	17.02
43	62	F	0.07	99.80	45.21	0.06	84.45	34.97
44	65	M	0.09	95.26	17.37	0.05	113.24	19.77
45	65	M	0.07	81.24	25.16	0.17	65.42	19.41
46	65	M	0.05	86.63	28.88	0.06	86.63	22.28
47	45	F	0.05	76.65	22.45	0.04	102.98	31.74
48	46	M	0.10	1O2.87	19.98	0.09	100.05	22.17
49	75	F	0.08	65.87	22.94	0.06	86.59	25.90
50	59	M	0.06	100.05	35.35	0.07	118.03	32.95

RIMT = Right Intimae Media Thickness, RPSV = Right Peak Systolic Velocity, REDV = Right End Diastolic Velocity

LIMT = Left Intimae Media Thickness, LRPSV = Left Peak Systolic Velocity, LEDV = Left End Diastolic Velocity

Table 2: Correlations

		AGE	SEX	RIMT	RPSV	REDV	LIMT	LPSV	LEDV
AGE	Pearson Correlation	1	-.049	.419**	-.356*	.315*	.465**	-.265	.185
	Sig. (2-tailed)		.734	.002	.011	.026	.001	.063	.198
	N	50	50	50	50	50	50	50	50
SEX	Pearson Correlation	-.049	1	-.119	-.085	.158	-.268	-.031	.186
	Sig. (2-tailed)	.734		.412	.556	.273	.060	.832	.195
	N	50	50	50	50	50	50	50	50
RIMT	Pearson Correlation	.419**	-.119	1	-.438**	-.201	.429**	-.329*	-.132
	Sig. (2-tailed)	.002	.412		.001	.161	.002	.020	.361
	N	50	50	50	50	50	50	50	50
RPSV	Pearson Correlation	-.356*	-.085	-.438**	1	.378**	-.242	.747**	.171
	Sig. (2-tailed)	.011	.556	.001		.007	.090	.000	.234
	N	50	50	50	50	50	50	50	50
REDV	Pearson Correlation	.315*	.158	-.201	.378**	1	-.002	.179	.500**
	Sig. (2-tailed)	.026	.273	.161	.007		.988	.214	.000
	N	50	50	50	50	50	50	50	50
LIMT	Pearson Correlation	.465**	-.268	.429**	-.242	-.002	1	-.310*	-.130
	Sig. (2-tailed)	.001	.060	.002	.090	.988		.028	.367
	N	50	50	50	50	50	50	50	50
LPSV	Pearson Correlation	-.265	-.031	-.329*	.747**	.179	-.310*	1	.343*
	Sig. (2-tailed)	.063	.832	.020	.000	.214	.028		.015
	N	50	50	50	50	50	50	50	50
LEDV	Pearson Correlation	.185	.186	-.132	.171	.500**	-.130	.343*	1
	Sig. (2-tailed)	.198	.195	.361	.234	.000	.367	.015	
	N	50	50	50	50	50	50	50	50

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

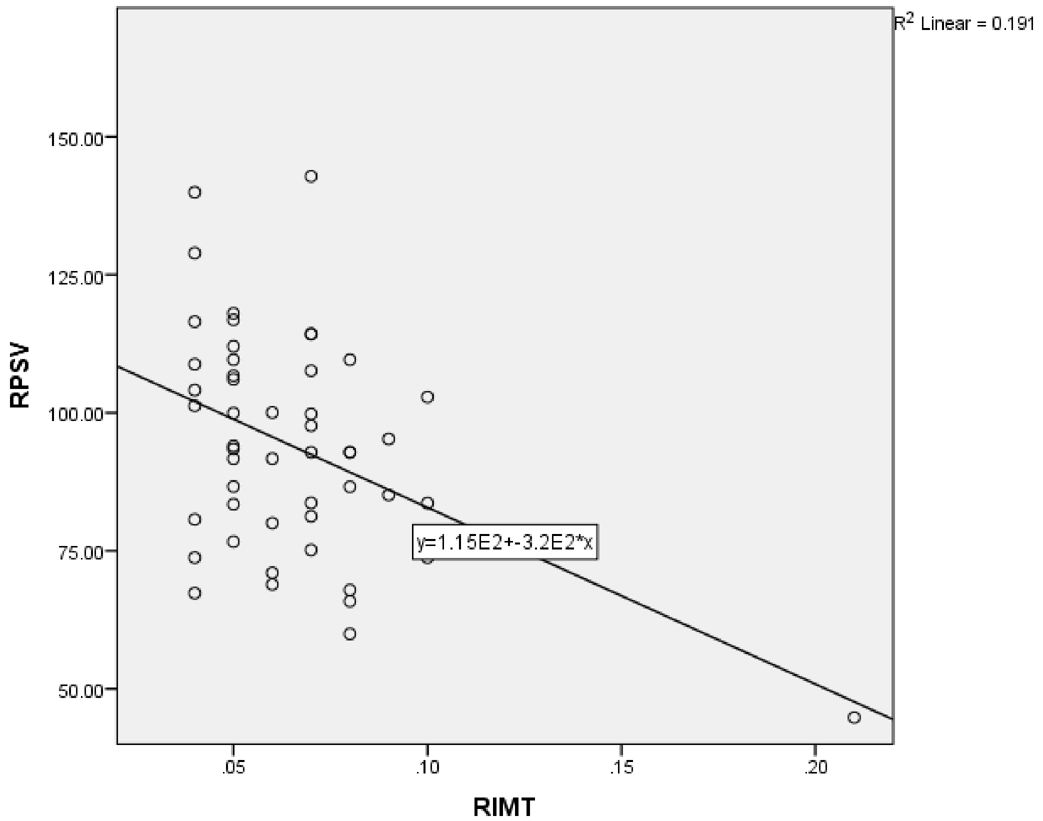

Fig 1: Regression Line between RPSV and RIMT

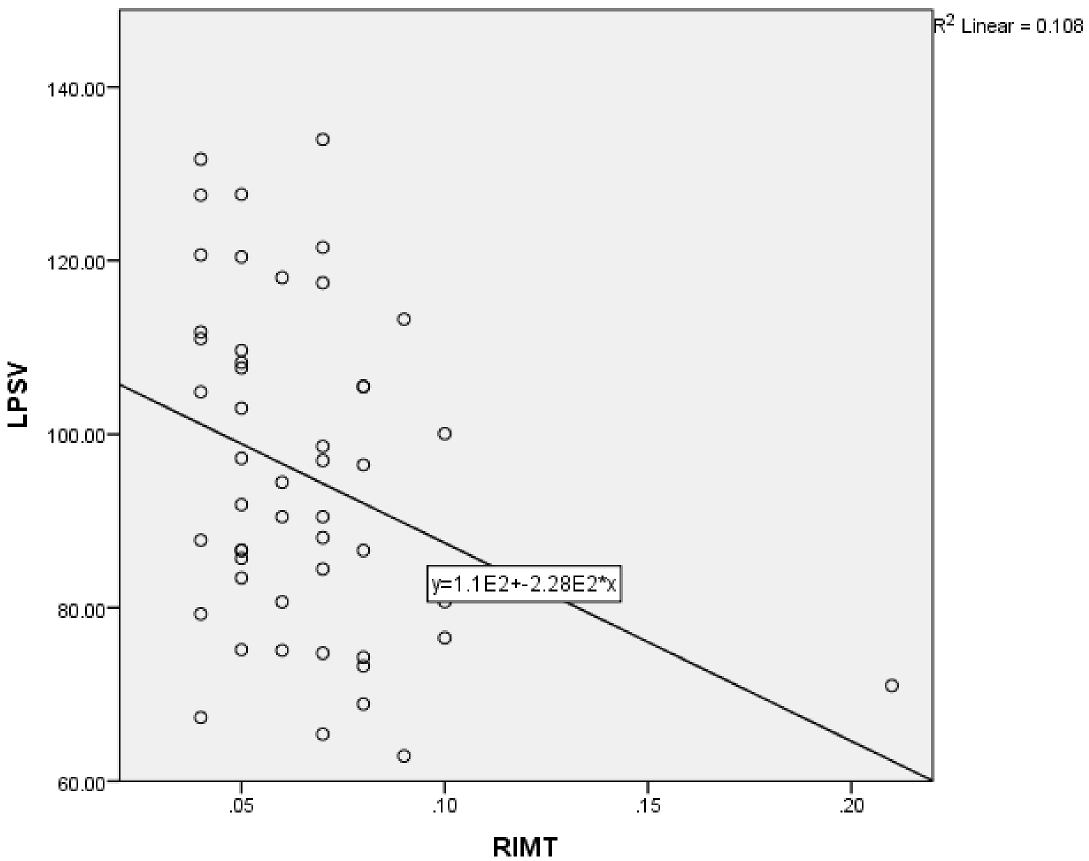

Figure 2: Regression Line between LPSV and RIMT

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