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Affecting Factors of Weight and Gender on Carotid Arterial Wall Motion: Diameter and Displacement Assessment

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Abstract: There are many cases that relate to the atherosclerosis disease due to the development of plaque inside the blood vessel. Several factors cause a person suffering from atherosclerosis disease are such as overweight, high blood pressure, unhealthy blood cholesterol level, and smoking habit. As the prevention, this work aims to detect the early stage of atherosclerosis disease which divided into gender and body mass index (BMI) categories. The focused parameters are diameter size and wall displacement of common carotid artery (CCA). In order to assess those two parameters, offline B-mode ultrasound images are used which then converted into grayscale images. All images are segmented to track the better edges of carotid arterial wall. We observed the correlation of CCA diameter and wall displacement to BMI and gender categories, where the diameter in overweight category own 9.7%, 4.8%, 14.8%, and 4.9% higher compared to underweight and normal weight categories, both in male and female groups, respectively. For wall displacement, it shows significant differences of 11% to 25% higher in overweight category compared to the other two weight categories. These findings suggest that the CCA diameters and wall displacement may reflect to the atherosclerosis before plaque formation, thus could be an important factor during the development of atherosclerosis. Moreover, the assessment conducted in both conditions; longitudinal and transverse images, confirmed there is only slightly error 7.4% and 7.2% for male and female groups.

Keywords: intima-media thickness, B-mode image, Canny edge detection method, body mass index

1. Introduction

Atherosclerosis is a condition which fatty materials such as cholesterols cumulate in the artery wall, known as plaque [1]. As the artery narrowing become severe, the plaque will block the blood flow causing blood to clot inside the artery at the site of the rupture. This phenomenon gives the potential of occurrence an infarction and ischemia stroke [2]. The carotid arteries are made up of three layers of tissues which are intima, media, and adventitia layers [3]. The distance between the farwall intima edge and nearwall intima edge is defined as the arterial diameter. Based on the arterial pressure-diameter relationship, the elasticity, inertial, and viscosity of arterial could be measured [armentano 1995b]. Thus, the determination on calculating the diameter becomes an essential methodology. Some techniques [4-6] used an algorithm in order to measure the arterial diameter neither in off-line and motion conditions. Most of the techniques become complicated when dealing with the speckle noise which degrades the image quality. Previously, one of the denoising technique proposed Bilateral Filter and Adaptive Wiener Filter (BL_Wiener) to denoise speckle noise existing in B-mode ultrasound images while preserving the original image edges, which the increasing of PSNR value [7]. We also suggested the Otsu-Canny method to determine the edge of lumen carotid artery, which obtained the high PSNR value [8]. However, the methodology is not reliable because the values are calculated based on the numbers of edges, which the PSNR value becomes higher when the image content more complex object. Thus, to determine the diameter, this work employed the Canny edge detection method on the carotid arterial B-mode image after the thresholding segmentation applied.

In conjunction, the wall displacement is affected by the movement of carotid arterial wall. The assessment of the wall displacement may not be neglected since the changes of diameter are proportional to the wall displacement. Moreover, data approved by the Institution Review Board of the University of Iowa demonstrated the difference of arterial wall thickness between the adolescents and adults [9]. Thus, the diameter and wall displacement of CCA in difference gender and weight should be taken into account. In addition, this work gives attention into two views that could be compared; longitudinal and cross-section views.

2. Data Acquisition

Gender and body mass index (BMI) are two parameters that assumed to be the factors of the value for common carotid artery diameter. CCA diameter are slightly different for both gender and one reported that males have a wider diameter size of the vessel compare to the size of the females. BMI of subject is strongly

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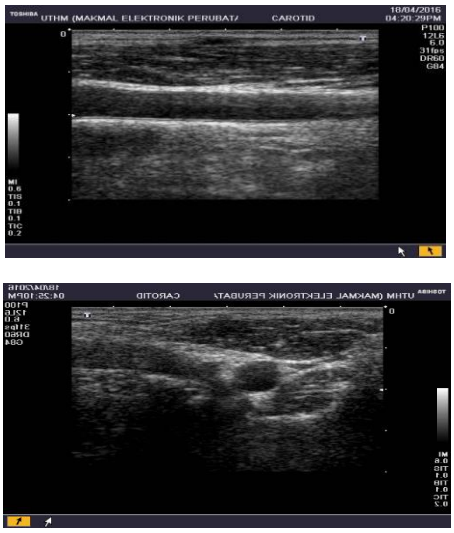
affected and have high correlated with the size of common carotid artery diameter. The analysis of vessel diameter and BMI shows the higher BMI value, the wider CCA diameter is obtained [12]. Moreover, the height and neck size also appeared to predict carotid artery diameter, presumably because BMI is a marker for nutritional and conditioning status [14]. This work is cooperated with 15 subjects for each gender and BMI categories; underweight (<18.5), normal (18.5 – 25), and overweight (25 - 30) [10]. The subjects are volunteer aged between 20 and 30 which not diagnosed as cardiovascular disease.

Ultrasound machine generates a high frequency of acoustic signal that suitable for the diagnosis. The signal propagates through tissue which then returns to the transducer as reflected echoes. The returned echoes are converted back into electrical impulses by the transducer crystals and are further processed in order to form the ultrasound image of human inner body. In this case, the image appears is the common carotid artery. This work takes the advantage of standard ultrasound machine typed Toshiba SSA-580A with 6-12 MHz linear probe. The images are recorded into an external frame grabber for further checking during analysis. Fig. 1 shows two types of view of carotid arterial image in longitudinal and cross-section positions.



(a)

(b)

Fig. 1 B-mode carotid arterial images in (a) longitudinal and (b) cross-section views

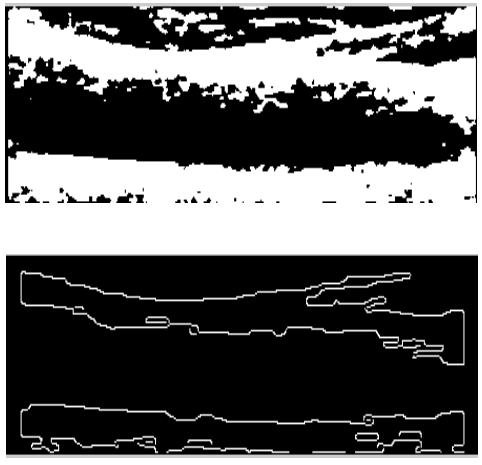
3. **Ultrasound Image Analysis**

This work involved several steps starting from the images data acquisition until the CCA diameter and wall displacement are measured. Firstly, image acquisition B-mode carotid arterial image is recorded. Since every subject has different carotid wall thickness, cropped image or region of interest (ROI) need to be selected to assess the diameter which is conducted manually. The region is converted from the B-mode image into the grayscale image before the image segmentation is proceed that involves the thresholding method. The purpose of thresholding is to extract pixels from some image which represent an object. In this case, the input to the thresholding method is the grayscale image of carotid artery, while the output is the binary image representing the edge detection of carotid artery image. Since the image has been converted into grayscale, there are only two values which are 0 and 1. The wall edge is detected applying canny edge detection method, to determine the intima boundary. The efficiency of the canny method is relies on multi-stage algorithm such as estimating the given edge to be detected as the edge or not. Moreover, the exact position of an edge is identified via thresholding process and suppression of edge which are not connected to a definite edge [11].

Four steps are operated in this method:

(a) Smooth the ultrasound image of carotid artery whose edges are to be found out using 2D Gaussian Function
(b) Find the gradient of the image
(c) Suppress all points that not at maximum value
(d) Thresholding the high and low value. If the value of the pixel is above the high threshold, it is set as an edge pixel. If value of pixel is above the low threshold and is neighbour of an edge pixel, it is also set as an edge pixel. If a pixel has a value above the low threshold but is not the neighbour of an edge pixel, it is not set as an edge pixel.

Figs. 2(a) and (b) show the post-processing carotid arterial longitudinal image after thresholding and employment of canny edge detection method.



(a)

(b)

Fig. 2 (a) Carotid image after thresholding and (b) applied canny edge detection method

To achieve the objective of this work, the step is proceed with the tracking of the carotid arterial diameter followed by the wall displacement assessment. Conversion from pixel unit to centimetres unit would depend on image visualized setting on ultrasound machine. By increasing the value of depth, it allows deeper structures of CCA to be viewed. Here, the scale is setup to be 1 cm = 81 pixels. The CCA diameter in pixel is measured by using "*imtool*" in MATLAB software. The carotid arterial diameter $d_{i,j}(t_n)$ (n = 1,2,…, N) is calculated as in Eq. 1, where N is the image frames, t is the time frame of N, i and j are

axial and lateral positions. Diameter value of 48 pixels is manually obtained from the B-mode image.

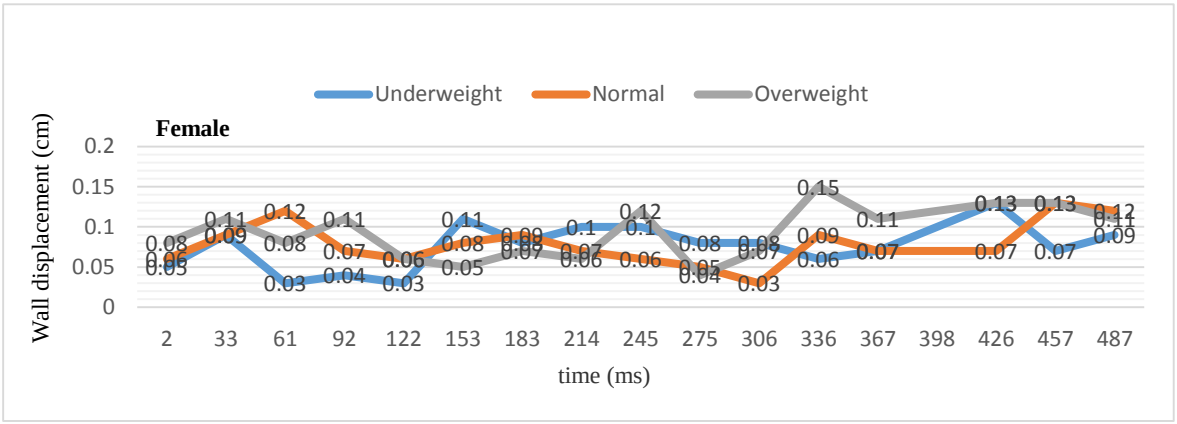
$$d_{i,j}(t_n) = \frac{48}{81} * 1\,\text{cm} \quad (1)$$

As the wall displacement $k_{i,j}(t)$ is defined from the carotid arterial wall motion, the difference of lumen diameter between two frames is expressed in Eq. 2 as follows;

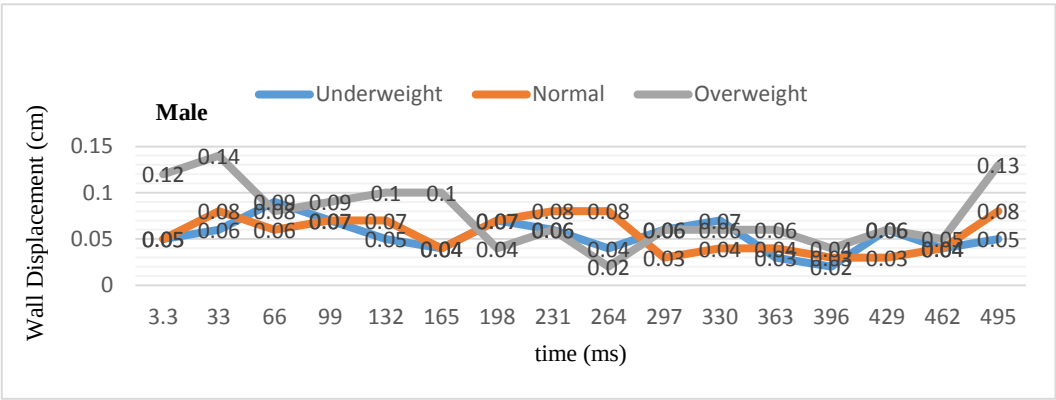
$$k_{i,j}(t) = \int_{t_{n+1}}^{t_n} d_{i,j}(t_{n+1}) - d_{i,j}(t_n) \quad (2)$$

4. Analysis Results

Fig. 3 shows the displacements during axial motion of 15 females and 15 males carotid artery. The analysis was conducted for 0.5 s of 16 frame images. Both male and female results performed the high values in overweight category. In contrast, the lower displacement was indicated in underweight category. However, it could be observed that the data was randomly calculated. To obtain the better and consistent data, the analysis should be done for the longer durations. As summarized in Table 1, the averaged diameter in both longitudinal and transverse views, and displacements values were gradually increased from the underweight category to the overweight category. In male group, the averaging diameter measurements in longitudinal view were 5.6 mm, 5.9 mm, and 6.2 mm for the underweight, normal weight, and overweight categories, respectively. The difference between the results obtained in the longitudinal and transverse views were 0.5 mm, 0.5 mm, and 0.3 mm for each categories. The same pattern appeared in the female group, which obtained only 0.6 mm, 0.3 mm, and 0.3 mm error for underweight, normal weight, and overweight categories, respectively. Those slightly error reconfirmed the diameter measurements even in difference views. It also could be observed that displacements value is increase proportionally to the subject weight, both in the male and female groups. It was assumed that arterial wall structure is changing during the alteration of atherosclerosis. The wall becomes thicker with the existence of plaque which lead to the harden wall and decrease the elasticity value [12]. Slower movement of wall indicates the high possibility of existence plaque. Thus, these results may contribute to the prediction of the early stage atherosclerosis. Further study is recommended to assess the elasticity and velocity of carotid arterial wall.



(a)



(b)

Fig. 3 Displacements measured during 500 ms segmented carotid images for (a) female and (b) male

Table 1 Diameter and wall displacement of carotid artery based on gender and weight

		Averaged measurement		
GENDER	**BMI**	Diameter in longitudinal view (cm)	Diameter in transverse view (cm)	Wall Displacement (cm)
MALE	Underweight	0.56	0.61	0.08
	Normal	0.59	0.64	0.08
	Overweight	**0.62**	**0.65**	**0.09**
FEMALE	Underweight	0.52	0.58	0.05
	Normal	0.58	0.61	0.06
	Overweight	**0.61**	**0.64**	**0.08**

5. Conclusion

This work aimed to study and assess the diameter and displacement of the carotid arterial wall movement from B-mode ultrasound image for the early detection of atherosclerosis. The assessment are divided into two groups; male and female, and into three focus categories; underweight, normal weight, and overweight categories. The results showed the method performance by observing the measurements in two views, which obtained the slightly error of about 7%. Also, the increment of displacements from underweight to overweight categories provides the prediction of early stage atherosclerosis.

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