ASSESSMENT OF CAROTID ARTERIAL WALL MOVEMENT FROM OFFLINE B-MODE ULTRASOUND IMAGE FOR EARLY DETECTION OF ATHEROSCLEROSIS

WAN FATIN LIYANA BINTI MUTALIB

UNIVERSITI TUN HUSSEIN ONN MALAYSIA
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WAN FATIN LIYANA BINTI MUTALIB

A dissertation project submitted in partial fulfilment of the requirement for the award of the degree in Master of Electric Engineering

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DEDICATION

Special for:

Beloved dad and mum,
Tuan Haji Mutalib bin Mohd Noor & Puan Hajah Wan Sharifah Mastura binti Wan Mahmud

Dearest grandmother,
Hajah Hasnah binti Hassan

Lovely sister and brother
Wan Fatnin Huda binti Mutalib, Muhammad Haziq Iqbal bin Mutalib
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Thank you.
ABSTRACT

Nowadays, there are many cases that relate to the atherosclerosis disease which is due to the development of plaque inside the blood vessel. There are several factors that can cause a person to suffer from this atherosclerosis disease which are overweight, high blood pressure, unhealthy blood cholesterol level and smoking. However, for early detection of atherosclerosis disease will be detect from the size of diameter and wall displacement of Common Carotid Artery (CCA) based on the gender and Body Mass Index (BMI). Hence, this project is aiming for assessment of carotid arterial wall movement from offline b-mode ultrasound image for early detection of atherosclerosis. Based on the highlighted parameters, the measurement of diameter and wall displacement of Common Carotid Artery (CCA) is obtained by using MATLAB software as references for detecting the early stage of atherosclerosis diseases. All images were enhanced and segmented in order to track the best position of carotid arterial wall. Then, the diameter and wall displacement of CCA were measured. The result were then analyzed based on BMI and gender. This study shows that the CCA diameters and wall displacement correlated with BMI and gender where the diameter and wall displacement of overweight subjects are bigger compare to normal and underweight subjects both in male and female group. These findings suggest that the CCA diameters and wall displacement may reflect to the atherosclerosis before plaque formation and can be an important factor during the development of atherosclerosis.
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\[\text{diameter of CCA} = \frac{x}{y} \times 1 \text{ cm}\]  \hspace{1cm} (1)

\[\text{WD CCA} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}\]  \hspace{1cm} (2)

Body Mass Index: \[\frac{\text{Weight(kg)}}{\text{Height(m2)}}\]  \hspace{1cm} (3)
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CHAPTER 1

INTRODUCTION

1.1 Project Background

The carotid artery is the major blood vessels in the neck that supply the blood to the brain, neck and also face. There are two carotid arteries which are one on the right and the other one on the left [1]. These arteries originate from different arteries but follow symmetrical sources. Figure 1.1 below shows the right and left common carotid artery (CCA) at the both sides of the neck. The part of carotid artery has a division into two part which is internal carotid artery that carries the blood to the brain while for the external carotid artery supplies the blood to the face neck.

![Image of carotid arteries]

Figure 1.1: The position of carotid artery [2]
The carotid arteries are made up of three layers of tissues which are intima, media, and adventitia [1]. For the intima, it is the smooth innermost layer in the carotid arteries. While, media is a muscular middle layer that made up of smooth muscle cells and elastic tissue. It lies between the tunica intima on the inside and the tunica adventitia on the outside. The outermost layer of carotid arteries is adventitia. Figure 1.2 illustrates the image of three layers of carotid arteries using an ultrasound machine.

![Image of carotid arteries layers](image)

**Figure 1.2**: The three layers of carotid arteries. [3]

Using the ultrasound machine and the assist of data analysis, the movement of the carotid artery could be measured. The physical properties of an artery can be described in terms of stiffness, distensibility, and compliance, which changes in those properties could predict the atherosclerosis disease [4].

The ultrasound machine is the non-invasive and has a very high speed to produce good image compared to other competing equipment such as x-ray computed tomography (CT), radionuclide emission tomography, and magnetic resonance imaging (MRI) [5]. Besides, ultrasound can be used repeatedly without compromising the patient and have low cost compare with other methods. Ultrasound has been used in a variety of clinical settings, including obstetrics and gynecology, cardiology and cancer detection. The main advantage of ultrasound is that certain structures can be observed without using radiation. The usage of ultrasound towards this research project is in cardiology detection. This research focuses early detection of atherosclerosis that defined as the hardening and narrowing of the arteries. The plaque of atherosclerosis can be found on Intima-
Media Thickness (IMT) of the carotid artery. It can be scanned by using ultrasound on the human surface neck to find the IMT of a person [6]. Figure 1.3 shows the plague that located in a common carotid artery that caused the increasing of IMT.

![Diagram of carotid artery with IMT](image)

Figure 1.3 : The plague in the common carotid artery that caused the Intima-Media Thickness disease [6].

Intima-Media Thickness (IMT) is the thickness of tunica intima and tunica media, the innermost two layers of the wall of an artery. The measurement of IMT is usually be done by external ultrasound and occasionally by internal, invasive ultrasound catheters. IMT is used to detect the presence of atherosclerotic disease in humans and more contentiously is to track the regression, arrest or progression of atherosclerosis [7]. In Figure 1.4 shows the IMT of near and far walls of CCA.

![Ultrasound scan of carotid artery](image)

Figure 1.4 : The ultrasonic scan of the right common carotid artery. The definition of the intima-media thickness is shown for a) the near wall and b) the far wall [8].
Atherosclerosis is a condition which gives a build-up phenomenon in the artery wall that will result as a thickness of fatty materials such as cholesterols [9]. This disease usually causes without any symptoms until middle or older age. But as narrowing become severe, the plaque will choke off blood flow and can cause pain. Blockages can also suddenly rupture, causing blood to clot inside an artery at the site of the rupture. This phenomenon gives the potential of occurrence an infarction and ischemia stroke [10].

In the common carotid artery, the movement of the inner layers of the arterial wall is around 0.1–1 mm, of the same size as the diameter changed. When, the presence of intramural shearing was detected a complicated movement of the arterial wall, so the pattern revealing that the mechanisms behind the movement are not easy to understand [11]. For longitudinal movement of CCA, it shows a distinct multiphasic bidirectional pattern with have a distinct antegrade movement in early systole and followed by distinct retrograde movement. In diastole, a second distinct antegrade longitudinal movement is seen before the vessel wall gradually returns to its initial position. In some individuals, they have differences in retrograde movement other than first antegrade movement. It is because the pattern of movement of CCA also affected their age and gender.

![Figure 1.5](image-url)  
Figure 1.5 : The differences between the carotid intimal medial thickness and carotid atherosclerotic plaque [12].
1.2 Problem Statement

The carotid artery is made up of three layers of tissues which are intima, media, and adventitia. When plaque exists in an inner wall common carotid artery (CCA), it could increase the Intima Media Thickness (IMT). The plaque that exists is made up of fat, cholesterol, calcium, and other substances found in the blood. Over time, plaque will become hardens and the arteries also will be narrow. This will cause the pressure in the blood vessel becomes higher and the lack of oxygenated blood to the brain will cause a stroke. Moreover, the blockage of the CCA that responsible to the abnormal oxygenated blood flow is begins from the atherosclerosis alteration. Atherosclerosis causes structural changes in artery walls that alter the physical properties such as diameter of CCA during pulsation and impair the pulsatile function of arteries [13]. Thus, the diameter and wall displacement of CCA could be a very important indicator to study the behaviour change due to atherosclerosis phenomenon. Therefore, this project focuses on the assessment of the diameter and wall displacement of the carotid artery for early detection of atherosclerosis disease.

1.3 Aim

This project aims for assessment of carotid arterial wall diameter and wall displacement from offline B-mode ultrasound image for early detection of atherosclerosis.

1.4 Objective

To achieve the above aim, the following objectives need to be accomplished:

- To develop algorithm for study the behavior of carotid artery wall in lateral and axial directions.
- To measure the diameter and wall displacement of the carotid artery by using MATLAB software and the equation related.
- To find the relationship between diameter and wall displacement of carotid artery values depend on Gender and Body Mass Index (BMI).
1.5 **Scope of study**

The scopes on this project are:

- The image of carotid artery that have been recorded and captured form the ultrasound machine.
- 15 healthy males and 15 healthy females ages between 20 until 26 years old that have been categorized by Body Mass Index (BMI), which is 5 subject for each BMI.
- There are two parameters that should be focused on this project which is the diameter of the artery and arterial wall displacement.
- The code will be programmed using MATLAB to calculate the diameter and wall displacement of the carotid artery in lateral and axial directions.
CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will explain about the previous study of carotid artery wall from B-Mode ultrasound image. In order to get an understanding of the flow of this project, the understanding of the theory is important to situate the research focus within the context of the atherosclerosis disease. There are a few cases that related to this project that has been revised. This chapter is also to establish the theoretical framework and methodological focus.

2.1.1 Common Carotid artery

The carotid artery is very difficult to examine because of the size of contour at the neck. From the previous paper, the average diameter of CCA was 6.5 mm in male and 6.1 mm in female [14]. The average diameter of CCA from this research could be a reference in this study. Moreover, there is a limitation that ultrasound cannot visualize the entire length of the vessel because the last portion of the carotid artery travels through the bone at the base of the skull [11]. There are a few factors that affected the common carotid artery diameter which are gender and body mass index. For the gender, there are different size of CCA diameter. There are comparison between males and females CCA diameter are slightly different where the result has been proved that males have a bigger diameter size of the vessel compare to the size of the female[12].
Other than that, Body Mass Index (BMI) of subject is strongly affected and have high correlated with the size of common carotid artery. It also gives a factor of the different size of CCA diameter. The analysis of vessel diameter between different Body Mass Index (BMI) shows positive associated with enlarging vessel diameter. Thus, the bigger BMI values, the bigger diameter of CCA [12]. Besides, BMI is the body size parameter that most often controlled. Moreover, the height and neck size also appeared to better predict carotid artery diameter in our patients, presumably because BMI is a marker for nutritional and conditioning status [14].

2.1.2 Ultrasound Imaging

Ultrasound imaging of the carotid artery is widely used in the diagnosis of atherosclerosis because it allows non-invasive assessment of the degree of stenosis as well as of plaque morphology. Interpretation of ultrasound images is often limited due to the non-systematic search patterns of humans, the presence of structure noise (camouflaging normal anatomical background) in the image, and the presentation of complex disease states requiring the integration of vast amounts of image data and clinical information [14]. Layers of the artery are seen as double-line layers of hyper-echoic tissue (appear bright white on ultrasound) that represent the boundary between the lumen–intima and media–adventitia. This distinct pattern allows for easy and reliable tracking of the motion of the arterial wall in the radial direction. Radial direction movements indicate distension of the artery and can be used to assess functional changes in the arterial wall, such as arterial stiffness [14]. In recent years, advances in ultrasound imaging have permitted capture of the motion of the arterial walls with a higher spatial resolution to elucidate motion in the long axis of the artery, parallel to the direction of blood flow. High-resolution B-mode ultrasonography have recently enabled us to evaluate and detect minimal atherosclerotic lesions in superficially located arteries such as carotid and femoral arteries, and minimal arterial wall abnormalities long before the appearance of structural narrowing and hemodynamic disturbances [12].
2.1.3 Atherosclerosis Disease.

Atherosclerosis involves narrowing of the artery lumen from the build-up of fat and cholesterol, which forms a plaque. Ultrasound imaging has widely been used to examine the effect of plaques on artery flow mechanics and has considerably advanced our understanding of the pathogenesis of atherosclerotic plaque [13]. For example, plaque increases blood flow velocities and alters flow patterns upstream and downstream of the plaque site. In Malaysia, the third largest fatal disease is stroke which also one of the top five leading causes of death [15]. This fatal disease was caused by abnormalities of the blood vessels that stopped brain to get an enough oxygen that was supplied from oxygenated blood through a blood vessel called artery. Report on National Stroke Association of Malaysia that has highlighted that there are 40,000 Malaysian are disabled due to stroke every year. It is because of the atherosclerosis disease that has been detected among the people. There are no symptoms that can be seen or realise by people because the atherosclerosis disease causes without any symptoms until middle or older age. So to know either the people are getting early detection of atherosclerosis must measure the Intima Medial Thickness (IMT). If the people are having a maximum value of IMT< 1.1 mm, who are regarded as being free of atherosclerosis based on IMT criteria [15].

2.2 Previous Cases that related.

2.2.1 A Study of common carotid artery behaviour from B-mode ultrasound image using Region Tracking Method [16]

This study reported the carotid artery behaviour using Region Tracking Method. It applied Canny edge detection method which uses a multi-stage algorithm to detect a wide range of edges in images and video that determined to be the main advantage by using this operator of edge detection [16]. There had several of step to interpret the image of the carotid artery that gets from the ultrasound which is using two dimensional Gaussian Function, find the gradient of the image, non-maximal suppression and edge thresholding [16]. Figures 2.1 and 2.2 explain the different
between the original image of CCA and CCA image after employed the canny edge
detection process.

Figure 2.1: The original B-mode image in Common Carotid Artery [16].

Figure 2.2: The image of Common Carotid Artery after canny edge detection
process [16].
2.2.2 Automatic Intima-Media Thickness Measurement of Carotid Artery Wall in B-Mode Sonographic Images [17]

The objective is to detect the intima and adventitia simultaneously, by proposed a new method called Dual-Line Detection (DLD) which uses the global information instead of the local information. The CCA was examined by turning the neck of the study subject slightly to the left side [17]. The transducer was positioned at the lateral side of the neck without compression on the inner jugular vein. The lumen was then maximized in the longitudinal plane with an optimal image of the near and the far vessel wall of the CCA. Thus, both near and far wall of CCA can be observed and the images are saved on a recorder for off-line processes [17].

Both the intima and adventitia information are taken (the anatomic knowledge) into consideration simultaneously, then it can solve the problem of detection of intima and adventitia. According to anatomic structure, intima and adventitia are quasi parallel. This is the basic prerequisite of DLD method. With this knowledge, the possible range of the distance between these two layers can be defined. The system has to cover the relations describing the IMT of the whole possible situations such as the echo gaps, noises near intima or adventitia, calcification on the vessel wall, bulk detection on bifurcation of CCA and so on.

This is the basic prerequisite of DLD method.

\[ Z_1 = I_s * (f_M + f_E) \]

\( I_s = \) sub image selected  
\( f_M = \) edge detector  
\( f_E = \) enhance detector

The MacLeod operator \( (f_M) \) is an edge detector and the enhancement operator \( (f_E) \) is to reduce the noise effect inside the intima-media complex. The implementation of Gaussian filter on the feature sub-image \( Z_1 \) for obtaining a smoother feature image \( Z' \). \( Z' \) is used for the initialization of the iterative DLD scheme. The image below shows the image of CCA wall that obtains from the ultrasound.
2.2.3 A New Approach for Estimating Wall Motion of B-Mode Common Carotid Artery using Block Matching Technique [18]

This research proposes a quantitative method for imaging the elasticity in biological tissues, namely elastography. The method consists in calculating two-dimensional (2D) local tissue strain through cross-correlation of radiofrequency (rf) segments for the estimation of the time shift resulting from a small deformation [18]. Mechanical displacements of the carotid artery wall can be quantitatively estimated from temporal sequences of ultrasound images. Within these sequences, radial and longitudinal displacements can be estimated by tracking the speckle patterns generated by the tissue [18].
The technique used was the block matching to estimate wall motion of the B-Ultrasound common carotid artery images. Figure 2.4 illustrates the block matching procedure clearly. In block matching, a block of pixels is given in the reference frame. The aim is to find a block in the given frame that best matches the reference block. The searching is done in the given frame within the search region. The size of the search region decides accuracy of the matching technique. To identify a matched block in the given frame (k), the correlation between the reference block and a block of pixels in the search region is obtained.

2.2.4 Automatic Measurement of Lumen Diameter of Carotid Artery in A-Mode Ultrasound [19]

A new method is proposed to estimate the diameter by using dynamic peak detection and shape fitting which is less prone to errors and more objective. The performance of the new algorithm was verified by simulation and phantom studies and measurements. The equation that has used was the compliance coefficient (CC) of artery [19]:

\[
CC = \frac{(\Delta D \times d_d)}{(2 \times \Delta P)}
\]

\(d_s\) = Systolic lumen diameter
\(d_d\) = Diastolic lumen diameter
\(\Delta D = d_s - d_d\)
\(\Delta P\) = Systolic pressure – Diastolic pressure
This equation is employed to measure the lumen diameter. The technique applies used to calculate the shape fitting and diameter estimation as using [19]:

\[
\text{Arterial diameter (D)} = \frac{\text{LEDW + TEPW} - S}{\text{PPMM}}
\]

LEDW = Leading edge of Distall wall  
TEPW = Trailing edge of Proximal wall  
S = samples  
PPMM = patient mismatch

The method was by Lumen of right half (LRH) and the lumen of left half (LLH) are extracted from RH and LH. So the result had interpreted as below.

![Figure 2.5 : The typical frame obtained from CCA.](image)

2.2.4 Detection of Lumen-Intima Interface of Posterior Wall for Measurement of Elasticity of the Human Carotid Artery [20]

In this journal, an example of off-line and manual processing of ultrasonic data for assessment of arterial wall elasticity is shown to illustrate the need for automatic boundary detection. For measurement of the elasticity of the arterial wall, the displacement of an object is estimated using the quadrature demodulated signal of the
received ultrasonic wave [20]. The lumen-intima boundary and the outer boundary of adventitia must be assigned manually with respect to the posterior wall to specify where the arterial wall is. This is done by manually tracing the B-mode image at time $t_0$ of the R-wave of the electrocardiogram reconstructed from the acquired quadrature demodulated signal as shown in Figure 2.6(b).

![Figure 2.6](image)

Figure 2.6: Procedure for measuring the elasticity of the arterial wall.

In the Figure 2.6, it shows the procedure for measuring the elasticity of the arterial wall which are for image (a) is about B-mode image of carotid artery, while image (b) is Manually assigned the lumen-intima boundary (LIB) and the outer boundary of adventitia (OBA) superimposed on the B-mode image reconstructed from the quadrature demodulated signal. Then, image (c) is an Electrocardiogram, image (d) and (e) is displacement, $x_{i-2}(t; l)$, of $(i-2)$-th point and displacement, $x_{i+2}(t; l)$, of $(i+2)$-th point. The last two image is (f) for displacement gradient (Change in thickness), $\Delta h_i(t; l)$, of $i$-th layer and image (g) for elasticity image [20].
2.3 Summary of literature review

In this chapter, the author thought to understand more about the terms and definition and the concept of carotid arterial diameter, movement, parameter, the technique to make an assessment of carotid arterial wall movement from offline b-mode ultrasound image for early detection of atherosclerosis. All of the words describe above are related to each other.

So in this project is to measure the value of diameter and wall displacement of carotid artery wall in two views which are lateral and axial direction. The method of image processing that used in this project is by using Canny edge detection method which uses a multi-stage algorithm to detect a wide range of edges in images and video that determined to be the main advantage by using this operator of edge detection [16].

Then, the diameter of carotid artery in two views which are lateral and axial direction will be measured by using “imtool” in MATLAB software. To ensure that the measurement of the same position, the coordinates of each subject have been deciding with a different position. It is because every human has different specific coordinates that cropped because of different size and diameter of carotid artery.
CHAPTER 3

METHODOLOGY

3.1 Flowchart of project

There is overall project development that has been shown in Figure 3.1. There are 4 main phases that involved in this research which are Phase 1(Image Acquisition), Phase 2(Pre-processing), Phase 3(Image Segmentation) and lastly Phase 4(Carotid arterial tracking).

![Flowchart of project](image)

End

Figure 3.1: Overall project development.
Figure 3.2: Flowchart for image processing
Figure 3.2 shows the flowchart for image processing. There are four phases that involve in this project. The first phase is about image acquisition which is collect the data image of Carotid Arterial in B-mode image. Then, the second phase is about select the Region of Interest (ROI), make the conversion Carotid Arterial image from raw data (B-mode image) to grayscale image and applied with Wiener Filter. Besides, the third phase is about image segmentation that involves the Local Adaptive Threshold and Morphology Operator. The lastly in the fourth phase is tracking the diameter of Carotid Artery.

3.2 Ultrasound Technique Scanning

3.2.1 Principle of ultrasound

Ultrasound is defined as a mechanical vibration with a frequency above the range of human hearing that is in the range between 500 KHz and 100 MHz [15]. The principle of the ultrasound unlike with other imaging modalities will measure the timed it takes for a short ultrasound pulse to travel to the object and echoed back again. In an overall view, ultrasound machine will generate a high frequency of acoustic signal suitable for the diagnosis and also the type of tissue that involved, then the signal propagate through tissue, and then return 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 for an example like common carotid artery that will present on the screen.

3.2.2 Scanning Technique

The carotid artery is one of the human inner body that is really hard to differentiate because carotid artery is almost look alike the muscle layer [10]. Therefore, to scan the carotid artery, the angle of 90° need to be adjusted to obtain the clear image of carotid artery as example shown in Figure 3.3.
Before scanning the part of carotid artery, the probe should be applied with the gel. It is because the gel acts as a medium between transducer and part of the body and also to ensure that there is optimum contact. In this project, by using Ultrasound machine (Toshiba SSA-580A) and with 6-12 MHz linear type B-Mode probe, an image of CCA is obtained. To ensure that the image that captured is common carotid artery, the Color Doppler will used to check the pulse during scanning process. In Figures 3.4 and 3.5, there are two types of image carotid artery that captured from the ultrasound which are in axial and lateral views.

Figure 3.3 : The position ultrasound probe during scanning process.

Figure 3.4 : Lateral section image of carotid artery at the neck section.
Figure 3.5: Axial section image of carotid artery at the neck section.

There are two parameters that have been considered which are diameter and wall displacement of carotid artery.

a) **Diameter of Common Carotid Artery (CCA)**

The measurements of CCA diameter are considered as the inner part, which is between an intima layer of near wall and the far wall [21]. When scanning the axial and lateral part of the CCA, the measurement of CCA in lateral part can be measured along the CCA while for axial part only can consider the measurement in one point of the origin.

\[
diameter \text{ of } CCA = \frac{x}{y} \times 1 \text{ cm} \tag{1}
\]

\(x = \text{Number of pixel diameter of CCA}\)

\(y = \text{Number of overall pixel ultrasound image}\)

Figure 3.6: (a) The measurement technique of CCA diameter for lateral view. (b) The measurement technique of CCA diameter for axial view [18].
Figure 3.6 shows the theory of diameter measurement from the IMT layer between near wall and far wall of CCA for lateral and axial view. The diameter of CCA is measured by using “imtool” in MATLAB software.

b) Wall displacement of carotid artery

In this project, both directions of wall movement carotid artery which are lateral and axial motions are been focused. By assessing the wall movement between the both direction, it could probably detect either there are plaques of atherosclerosis or not [21]. If the movement of the wall is slow, the possibility of plaque exist is high.

Wall displacement equation = N2 (t) – N1 (t)

\[ WD \text{ CCA} = \sqrt{(x2 - x1)^2 + (y2 - y1)^2} \] (2)

3.3 Ultrasound image analysis

Image that captured from ultrasound machine needs to be visualized and analysed by using the MATLAB software. MATLAB is a high-level language and interactive environment for numerical computation, visualization, and programming. Using MATLAB, the user able to analyse data, develop algorithms, and create models and applications [24]. Firstly, the images will be recorded as 10s video. By using MATLAB software, the obtained 10s video will be converted into time frame image.
The greyscale image will setup at the MATLAB during the image processing. The carotid artery tracking will be detected using the ‘imtool’ in MATLAB software.

### 3.3.1 Pre-processing Image

Image of carotid artery that obtains will be converted into the grayscale to fix the size and shape of the image. This process is to facilitate the interpretation of ultrasound image through the image reduction and edge enhancement. The greyscale image then undergoes the filtering techniques in image segmentation. In this project, three types of filtering which are Gaussian blur (Gaussian filter), Median filter and Histogram Equalization filter are used. When the SNR value is high and the noise is low, the image has high resolution and the clearer image is produced. Edge detection is one of technique that used in the image processing to extract useful information. In medical research, edge detection is an important method that applied for object recognition of the human organs such as lungs and ribs, and it is an essential pre-processing step in medical image segmentation [22] [23]. By using MATLAB software, there has a several types of edge detection with a specific command that represent the different function and advantages such as Robert operator, Sobel operator, Prewitt operator, and Canny operator. In this study, the proposed edge detection operator is a canny operator. There have several types of edge detection that used in image and video processing. In industries, the standard edge detection method that is usually considered to use is a canny operator [24]. Canny operator is more approximate and way, compared to the previous method, which has a complex exponential solution. Besides, the canny edge detection used to detect the wide range of edges in images and also video.
Image of carotid artery after image processing

The original image was cropped according to the specified coordinates which are at [91.5 127.5 453 117] as shown in Figure 3.8.

![Image of carotid artery after image processing](a) ![Carotid Artery image in the specific coordinate](b)

Figure 3.8: (a) Image of carotid artery, (b) Carotid Artery image in the specific coordinate.

Every subject has different specific coordinates that cropped because of different size and diameter of carotid artery. After that, image crop will convert into grayscale to fix size and shape of image. This process is to facilitate the interpretation of ultrasound image through the image reduction and edge enhancement.

The grayscale image then undergoes the filtering to removes noise. It is because most of the imaging ultrasound are contaminated with noise. Therefore, filtering is introduced to reduce the noise in order to clearly visualise the shape of the carotid artery. In this project, Wiener filter is applied because of Wiener is one of the most fundamental noise reduction methods. In addition, this filter has been implemented widely in the noise reduction in ultrasound image. Other than that, Wiener filter also performs smoothing of the image based on the computation of local image variance. When the local variance of the image is large the smoothing is little on the other hand if the variance is small, smoothing will be better [27]. Besides, Wiener filter can be used as decorrelator of speckle, which makes its distribution more in reflectivity. If reflectivity is reasonably assumed to be corrupted by multiplicative noise then eliminate such noise [28].

Next, the image will undergo the local adaptive thresholding. There are two types of thresholding based method namely local and global. In this process, local adaptive is applied as it can overcome the limitation of conventional threshold method when the image background or the feature intensities are not homogeneous. In contrast, global
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