Study of Vein Mechanism on Pregnancy Condition for Early Diagnosis of Deep Vein Thrombosis

Noor Hafizzatul 'Izzah bt Mat Harun, Nabilah bt Ibrahim, Nur Shazilah bt Aziz, Wan Nurshazwani binti Wan Zakaria and Nik Farhan bin Nik Fuad

Abstract In this paper, the study is conducted as an effort to provide better visualization of vein mechanism properties between healthy subjects and pregnant subjects. Here, it is proposed to evaluate the vessel condition for the pregnant subject and comparison to the healthy subject is done. Pregnancy had been one of the risk factor that contributes to the development of thrombus in the vessel which called Deep Vein Thrombosis (DVT). The DVT condition usually diagnosed using the ultrasound which is non-invasive, by monitoring the development of thrombus in the vessel. In this study, evaluation on two important parameters which are the measurement of the vessel wall displacement and also the blood flow velocity in the vein was done. It is believed that these two elements are crucial to construct a clinical model of Deep Vein Thrombosis (DVT) risk factor, which constitutes an important contribution for predicting probability of the development of Deep Vein Thrombosis (DVT) and help in preventing this condition.

Keywords Ultrasound · Wall displacement · Blood flow velocity · Pregnancy · Deep vein thrombosis (DVT)

N.H.'I. bt Mat Harun (✉) · N. bt Ibrahim · N.S. bt Aziz · W.N. binti Wan Zakaria
Faculty of Electrical and Electronic Engineering, UTHM, Parit Raja, Malaysia
e-mail: hafizzatul215@gmail.com

N. bt Ibrahim
e-mail: nabilah@uthm.edu.my

N.S. bt Aziz
e-mail: nurshazilahaziz@gmail.com

N.H.'I. bt Mat Harun · N. bt Ibrahim · N.S. bt Aziz
Microelectronics and Nanotechnology-Shamsuddin Research Centre, UTHM, Parit Raja, Malaysia

N.F. bin Nik Fuad
Department of Radiology, Pusat Perubatan UKM, Cheras, Kuala Lumpur, Malaysia

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1 Introduction

Venous thromboembolism (VTE) is a single disease affecting the venous circulation. It has two distinct presentations of condition that are the deep vein thrombosis (DVT) and the pulmonary embolism (PE) [1]. The DVT condition commonly occurs in the deep vein of the lower limb or pelvis. The clot developed in the vein, it forms deep in the body that can lead to DVT and PE [2]. Venous thrombosis is believed to begin at the venous valve [3]. On the other hand, for the Asians population; the rate of incidence of deep vein thrombosis condition seems low based on the cases reported. Even though, it is believed that the Asians population also suffered from this fatal condition [4, 5].

Therefore, awareness on this particular problem of diagnosing DVT is important. Factor that can contribute to DVT is stasis or stagnant blood through the veins which can increases the contact between the blood and the vein wall irregularities. Moreover, prolonged the bed rest or immobility will leads to stasis. Besides, coagulation also contributes to the clot formation [6]. In this study, the research focused on the evaluation of the vessel condition during pregnancy. During pregnancy, physiologic and anatomic changes can complicate the diagnosis of DVT as well as the management of patients with a high danger of established DVT.

A few studies have reported a striking inclination for DVT during pregnancy to happen in the left leg, this is perhaps due, probably because of the pressure of the left iliac vein by the privilege iliac supply route as they cross [7]. However, there is no definite indicator that can support the probability of the thrombus development in the subject's vessel. Therefore, this study is as an effort to determine indicator which can help in detecting early probability of the DVT condition and help in treating or improving the subject condition.

A variety of diagnostic techniques have been used to identify DVT which include the impedance plethysmography, contrast venography, ultrasonography, computed tomography, and magnetic resonance imaging [8]. Among these, ultrasonography is as accurate as any, with more advantages than others including low cost, portability, non-invasive, and simplicity [9, 10]. Therefore, in this project, the application of ultrasound is used to study the vessel and valve mechanism for the early diagnosis of DVT condition.

2 Research Design

2.1 Data Collection

To study the vessel condition during pregnancy and also normal condition, subjects had been gathered voluntarily for the assessments to be done. In this study, consent from each volunteered subjects taken from the university has been obtained for the diagnosis to be done. The experiment procedure had been explained properly to the subjects. The subjects had been categorized into two cases. For Case 1 are healthy subjects and for Case 2 are pregnant subjects. As for the healthy subject, they had been classified into three categories of weight based on their BMI (underweight, normal weight and overweight categories). There are three volunteered subjects for each category. Therefore, a total of 12 subjects had been gathered for this study. Based on the diagnosed done, it is to observe and to visualize the different vein mechanism between the healthy subjects with no history of DVT and pregnant subject.

The subject had been diagnosed using TOSHIBA SSA-580A ultrasound machine. In the scanning of the leg, the linear transducer with frequency range of 6–12 MHz is used [11]. Generally, the purpose of linear array transducer is for the scanning of superficial structures and vessels. The patient can be placed in either a prone or decubitus position, or seated on the edge of the gurney with the knee flexed and the foot supported. In the decubitus and prone positions, the leg being examined should be down. Next, 30 frames per second (fps) as data acquisition to assess the vessel wall displacement in the vein. Finally, the blood flow velocity in the vein is diagnosed using Power Doppler. The measured values are before and after the valve, were to observe if there is any significant different between the blood flow velocity before and after the valve.

2.2 Region of Interest (ROI)

In the study, the region of interest (ROI) is focused around the valve position in the popliteal vein. The ROI selected due to the need of measurement for the displacement between the popliteal vein walls. The patent of valve movement demonstrates the opening and shutting of valve during the blood flow. Besides, by having the valve scanning range, it will permit to measure the critical changes of the popliteal vein wall displacement. Figure 1a shows the transverse image of the popliteal vein and popliteal artery taken from the ultrasound. Figure 1b shows the longitudinal image of the popliteal vein and popliteal artery taken from the ultrasound. It shows the popliteal vein is at posterior position while the popliteal artery is at the anterior position [12, 13].

In the evaluation of the images obtained from the leg scanning; Canny edge detection method had been used for the process. The Canny method finds edges by looking for local maxima of the gradient of the image. The method uses two thresholds to detect strong and weak edges [14, 15]. Canny operator is the result of solving an optimization problem with constraints. The method can be seen as a smoothing filtering performed with a linear combination of exponential functions, followed by derivative operations [15].

Figure 2a shows the scanning of the valve located in the popliteal vein using the ultrasound machine. The image processed using the MATLAB software. It calculates the gradient using derivative of the Gaussian filter. After determining the edges of the vessel wall, the measurement of the wall displacement is collected.

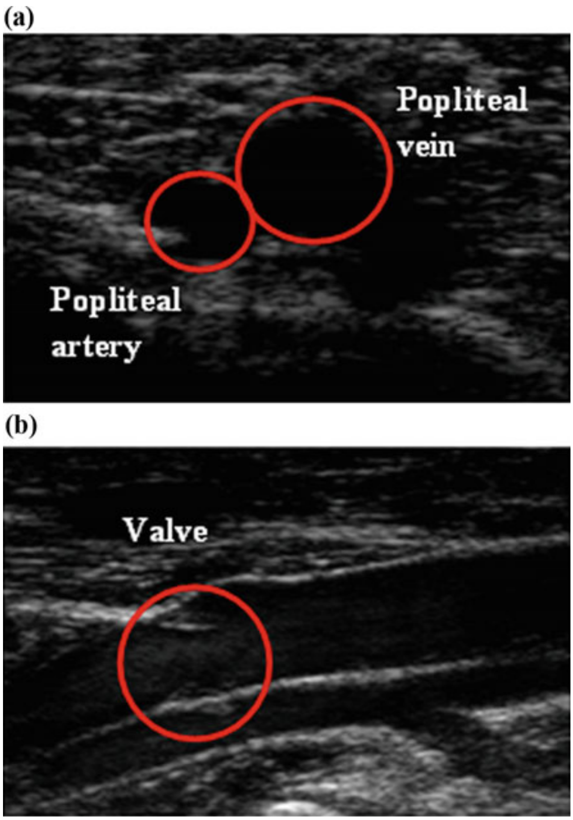


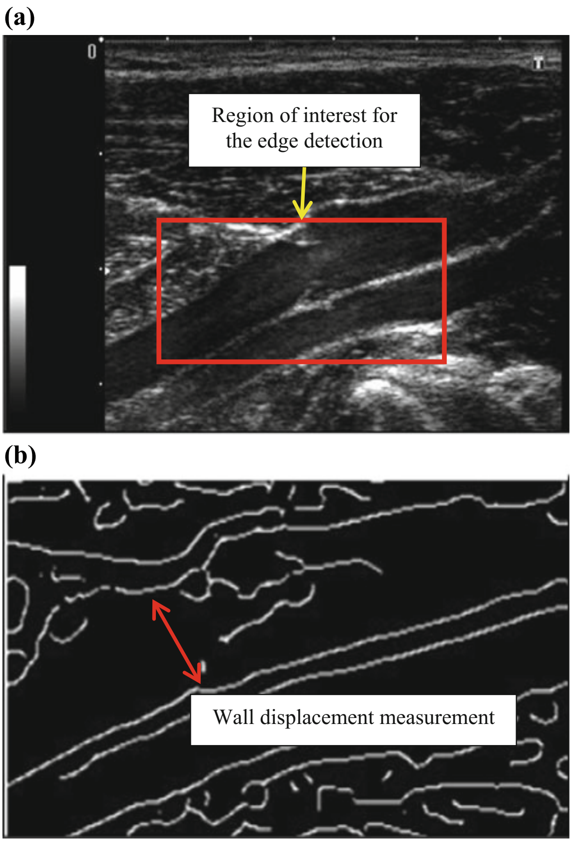
Fig. 1 Ultrasound images **a** the transverse image of the popliteal vein and popliteal, **b** the longitudinal of Doppler ultrasound image of popliteal vein

Figure 2b shows the marked region in the image were to determine the displacement of the vessel wall. The marked point specifically marked at the area near the valve to observe the displacement changes of the vessel wall. This is due to the thrombus developments that usually form in regions of slow or disturbed flow in large venous while for the deep vein of the calf; the thrombus usually forms in the valve cusps pocket [16]. Therefore, measurement of the wall displacement at the area near the valve is essential to evaluate the vessel wall elasticity.

2.3 *Vessel Wall Elasticity Measurement*

In this study, the elasticity of the vein obtained from the calculation. In order to obtain the elasticity, stress and strain measurements are required. Below shows an equation analogous to Hooke's law describes the relationship between stress and strain [17]:

Fig. 2 **a** The original image of the popliteal vein (B-mode ultrasound image), **b** Canny edge map of (**a**)



$$E(Pa) = \frac{STRESS}{STRAIN} = \frac{\sigma}{\varepsilon} = \frac{\frac{F}{A}}{\frac{L - L_0}{L_0}} = \frac{FL_0}{A_0 \Delta L} \quad (1)$$

where

E: Young's modulus (modulus of elasticity)
F: Force exerted on an object under tension
A_0: Original cross-sectional area through which the force is applied
ΔL: Amount by which the length of the object changes
L_0: Original length of the object

Stress is the force per unit cross-sectional area (F/A). Strain is the fractional increase in length, that is, $(L - L_0)/L_0$. The wall displacement measurement is to indicate the strain value for the elasticity of the vein. The stress values obtain from the blood pressure measurement in the vein over the area of the vein. Since the blood pressure of the vein is hard to be obtaining, therefore, the value used for the stress measurement in the physiologic condition is based on previous study which is 10 mmHg [18].

3 Result and Discussion

3.1 Blood Flow Velocity

As previously mentioned, to assess the blood flow velocity in the vein, Power Doppler ultrasound has been used. The assessment was done at the area near the valve. The precise locations were taken from the blood flow before and after the valve. It is necessary for the assessment done before and after the valve because to observe the possibilities of the relationship between the blood flow velocity and the probability of thrombus development. Figure 3a and b show example of the gate position used for the velocity of the blood flow measurement.

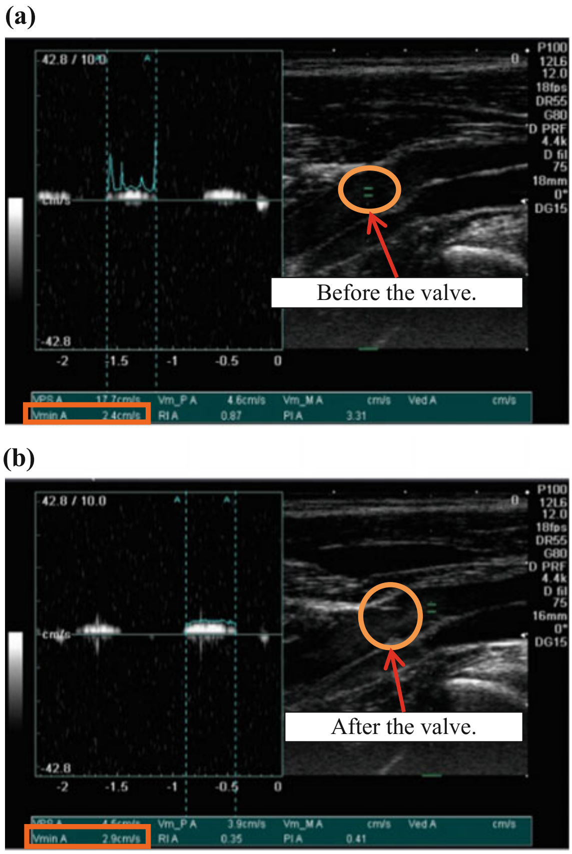


Fig. 3 Gate position **a** before the valve, **b** after the valve for the measurement of the velocity

Table 1 The value of blood flow velocity in the popliteal vein

Category	Velocity (cm/s)	
	Before valve	After valve
Underweight (BMI < 18.5)	8.27	10.61
Normal weight (18.5 < BMI < 24.9)	9.87	11.29
Overweight (BMI > 24.9)	9.73	16.13
Pregnant	5.56	5.52

Table 1 shows the velocity values obtained from the assessments. Currently, the assessments for the blood flow velocity were done for the subject with no history of Deep Vein Thrombosis that had been categorized into three categories based on their body mass index (BMI) and also the assessments from the pregnant subjects. Based on the result obtained, it shows that the velocity of the blood flow is increasing after passing through the valve for the healthy subject with no DVT, while the measurement show different pattern for the pregnant subjects which shows decrement of the velocity value.

In comparison between the three categories of BMI, it shows that the velocity increment after the valve for the normal weight category is lower than the overweight and the underweight category. Though, for the pregnant subjects' category possess the lowest changes of the blood flow velocity compares to the other three categories of subject of normal health condition with different BMI.

3.2 Vessel Wall Elasticity

In the strain-elasticity measurement, the values obtained from the assessments done used to measure the wall displacement. The measurement was taken from 60 frames of B-mode ultrasound images that had been extracted from the recorded video. Since the images are recorded for 30 frames per second, therefore, for this analysis the time frame of the wall movement is in range of 2 s vessel wall movement (60 frames of image).

In a better view, Fig. 4 shows the measurement of the average value of vessel wall strain-elasticity for all subjects' categories. The distribution shows the increment of the strain, resulted on the decrement of the elasticity values and vice versa. This applies to all the measurement done for all the subjects. The distribution observed that the overweight category possess the lowest strain percentage which is 0.5618 %, followed by the pregnant category with value of 0.6314 %. As for the underweight and normal weight category have 0.7513 and 1.0243 % of strain percentage value respectively.

In contrast, the elasticity value of overweight category reaches the highest value of elasticity compared to the rest of the category which is 0.5005 MPa. Second to the highest elasticity value is from the pregnant category with value of 0.4924 MPa, followed by the normal weight t category and underweight category which values

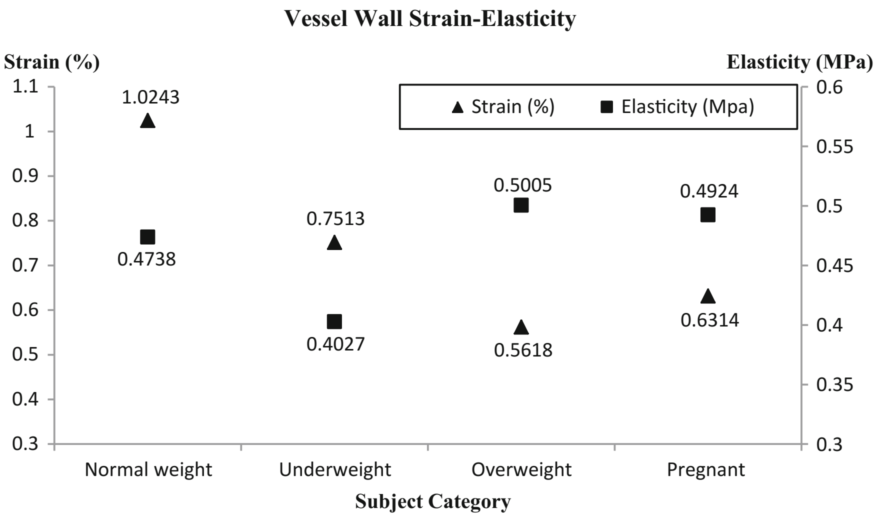


Fig. 4 Vessel wall strain-elasticity measurement

are 0.4738 and 0.4027 MPa respectively. Previously, a study by N. Harun et al. shows findings on the overweight category that has the highest range of the vessel wall elasticity compared to the other weight category [19].

In previous study, contrast to the arterial system, the lower pressure in the venous system not undergoes large changes in capacity without major pressure changes [20]. In the study, it has been stated by Attinger that the cross section of the venous segment may oscillate between complete collapse and full distension depending upon the interplay between intravascular and extravascular forces in relation to the stiffness exhibited by the vascular wall at any given time. Though, some factors that might be affecting the measurement are the muscle bulk at the leg of subjects and also the tissue layer content at the region of scanning. For pregnancy condition, this would be the probability of the changes in hemodynamic conditions of the body which affect the blood flow in the vessel.

4 Conclusion

In a nutshell, this study investigated the vessel valve behaviour for the pregnant subject as well as comparing to the subjects with normal health condition. The parameters that had been measured were the wall displacement and blood flow velocity of the vessel. The elasticity of the vein shows the difference of the vessel condition for different weight categories and also the pregnant subjects. Significantly, the data shows that the pregnant subject has the vessel wall elasticity measurement approximate to the overweight subject. While the underweight and normal weight category has lower value of vessel wall elasticity. Therefore, this allows the probability in proving the pregnancy and obesity that would be the risk factor of the thrombus development in the vein. Though, the clinical experiments done with the main purpose of the study which is to diagnose the early-stage of Deep Vein Thrombosis (DVT). In the future, the clinical data of DVT patient could be obtained, so that the comparison between those parameters on the DVT patient could be realized. The comparison will also be referred as the validation to predict the early-stage of DVT.

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