Biomedical Sciences
2019; 5(4): 38-44
http://www.sciencepublishinggroup.com/j/bs
doi: 10.11648/j.bs.20190504.11
ISSN: 2575-3924 (Print); ISSN: 2575-3932 (Online)

Diagnose the Size of Left Atrial Appendage for Watchman Device

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To cite this article:
Hamidreza Khezri, Mojtaba Farzaneh. Diagnose the Size of Left Atrial Appendage for Watchman Device. *Biomedical Sciences*. Vol. 5, No. 4, 2019, pp. 38-44. doi: 10.11648/j.bs.20190504.11

Received: September 26, 2019; **Accepted**: October 14, 2019; **Published**: October 28, 2019

Abstract: Nowadays Atrial Fibrillation (AFib) has been highly epidemic that is a heart condition causes the heart in an irregular rhythm and can increase the risk of stroke. The Left Atrial Appendage (LAA) which is a part of the heart is the main source of thrombosis in patients with AFib. Since AFib patients are at risk of developing clots in LAA, it is, therefore, necessary to detect the LAA anatomy and closure of LAA to prevent stroke. For some reason, such as the presence of different muscles in the heart and the irregular anatomy of LAA, detecting and determining the exact size of the LAA is difficult. In this paper, we present a fully automatic approach to diagnose the LAA and measure its size based on the inlet orifice and the depth of the LAA primary lobe for the implant by the WATCHMAN device. These processes utilize images that were taken by echocardiography (Echo) from the heart of patients and analyses at high speed with precision, and used the standard table provided by the manufacturer (WATCHMAN) and Neural Network (NN) to determine the accuracy the appropriate size of LAA for left atrial appendage closure (LAAC).

Keywords: Atrial Fibrillation (AFib), Left Atrial Appendage Closure (LAAC), WATCHMAN Device, Stroke, Echocardiography (Echo)

1. Introduction

As we know, medical imaging diagnostic tools such as Echocardiography (Echo) and Computed tomography (CT) have made a lot of progress. For cardiovascular disease, these can greatly help physicians to get LAA information and predict the risk of thrombosis [1].

Since atrial fibrillation (AFib) causes the volume of LAA increases and on the other hand the cardiogenic thrombi (Figure 3) occur mainly in the LAA and approximately 80% of the cardiovascular thrombosis causes a stroke. So can say thrombotic diseases have become a serious threat to human health [2]. The LAA shape is irregular, with a hook and a few lobes. Its size varies from 1 to 19 cm³ [3].

This study is base on Echo data and with respect to the small and variable structure of LAA, we have to focused on LAA in the image processing domain. There is no automatic method for detecting LAA size by Delphi software and NN for LAAC (Figure 4).

Delphi software is used in this work, which has the following advantages compared to other software such as Matlab:

1. Very high speed
2. All process run full automatically
3. User-friendly
4. Compatible with all windows

The main steps of our proposed method are the following:

- We propose a new method for diagnosing LAA. Our pproach can precisely identify the LAA size and lobes that have been lost in most of the previous research [4, 5].

a) We propose a quick multi-stage LAA method based on 2D Echo data to obtain information that has not been discussed in previous studies.
b) All images in three steps are processed at very high speed and accuracy. The images that included LAA are stored.
c) We calculate the LAA area and get information about each image [6].
d) We using a Neural Network and the standard table of

the WATCHMAN device to detect and accurately measure the size of the LAA.

This research provides a potential for the implant by WATCHMAN device and closure of LAA to prevent stroke in patients with AFib.

1.1. Introduction to Atrial Fibrillation (AFib)

Atrial Fibrillation or AFib is a heart condition that causes the heart or beat very fast and in an irregular rhythm. AFib can increase the risk of heart stroke and even death, and can worsen over time. It is important to have it diagnosed early and cared for appropriately [7]. AFib is the most common type of irregular heartbeat or arrhythmia. It affects over 3 million people in the United State alone. The heart is a muscle that acts as a pump and squeezes with each beat to push blood to the rest of the body. The heart has four chambers. The two upper chambers are called atria and two lower are called ventricles. Under normal conditions, the upper and lower chambers of the heart work together to pump blood throughout the body. Blood flows into the atrium, where blood is regularly fed into the ventricles, from which the blood passes through the ventricles to different parts of the body. In a healthy heart, electric signals travel through the heart in a regular steady rhythm or pattern. These electrical impulses originate in a special section of the atrium and travel through the heart in a regular pattern. Each signal ultimately causes the heart to beat. AFib occurs when electrical signals start in the wrong place and misfire. The fault signals cause the atria to quiver and not contracts completely [8].

The number of factors such as age, family history, smoking, high blood pressure or hypertension and obesity that increase the chances to get AFib. Also, if anyone has any of these conditions, they are at risk for AFib heart failure, diabetes, or coronary artery disease [9].

As we see in the Figure 1, we have three types of AFib. These named as paroxysmal, persistent and permanent AFib respectively. The red lines represent AFib episodes and the blue lines represent times when the heart is in rhythm. When many patients are first diagnosed, they experience periods of AFib that may come and go. Second, in some situations, need to perform a procedure or provide medicine for cardioversion to bring the heart back to a normal rhythm. Third, in some people who have had AFib for a long time, the heart may not be able to return to a normal rhythm at all and the risk of a stroke is very high [10].

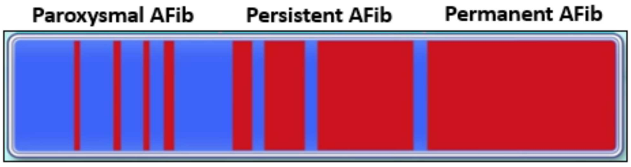

Figure 1. *Different types of Atrial Fibrillation (AFib).*

People with AFib are 5 to 7 times more likely to have a stroke than the general population. Note that over time the red areas are larger and more frequent [11].

1.2. Symptoms and Consequences of AFib

There are many signs and symptoms of AFib. These symptoms like dizziness, shortness of breath, chest pain might be subtle or severe and some people feel tired or weak. In fact, 60% of patients do not even know when they have an AFib episode. It is important to know that while symptoms may not be felt at all times, the heart may still be out of the rhythm and still be at risk for other complications, such as remodeling or stroke [12].

AFib can change the size and even the shape of the heart through a process called remodeling. Remodeling can cause permanent changes in the heart in a very short amount of time. During AFib, blood can collect or pool in the heart and cause a clot to form. If this happens, the clot can travel from the heart to the brain and cause a stroke [13].

1.3. Comprehensive AFib Management

AFib treatment guidelines for healthcare providers recommend a comprehensive approach to the treatment of all AFib risks. This guide prioritizes the three goals of treatment, rate control, maintain normal rhythm, and prevent stroke. Healthcare providers may offer a range of common therapies to manage the risks and symptoms of AFib [14].

1.3.1. AFib Treatment: Rate Control

There are several ways AFib is treated. One of them is a medication to reduce the heartbeats. Notice that the rate of medication slows down the heart rate. However, the heart continues to beat irregularly and without rhythm. Rate control medications do not correct the rate of irregular heart rhythm associated with AFib [15]. They slow the heart rate but do not consider the rhythm or AFib pattern.

1.3.2. AFib Treatment: Rhythm Control

When rhythm control medication is used. The heartbeats in normal rhythm, but remains fast. Rhythm treatment regulates your heart rhythm but may have little or no effect on the rate at which your heartbeats [16, 17].

The use of blood thinners, such as warfarin (Coumadin), reduces the risk of stroke in patients with atrial fibrillation. Many patients are worried about taking warfarin. Some of the reasons for this are:

Frequent blood draws are needed to measure the patient's international normal ratio (INR), or clotting time. The tests are needed to make sure the patient takes the right amount of medication.

The risk of bleeding is higher while taking warfarin.

Some patients do not tolerate warfarin or have trouble maintaining a normal INR [17].

1.3.3. AFib Treatment: Medical Procedures and Devices

Other treatments for AFib may include surgical and nonsurgical procedures and implanted devices. Surgical ablation is a surgical procedure to destroy the cells causing abnormal heart rhythm. It may be used when other treatments have not worked. The surgeon treats the surface of the heart directly rather than relying on catheters and x-rays to reach the heart. For some patients, a small battery-powered device called an atrial pacemaker may be implanted under the skin to generate electrical signals to regulate heartbeat [18].

2. Left Atrial Appendage (LAA)

The left atrial appendage (LAA) is a small, pear-shaped sac in the muscle wall of the left atrium (LA) (top left chamber of the heart). In normal hearts, the heart contracts with each heartbeat, and the blood in the LA and LAA is squeezed out of the LA into the left ventricle (bottom left chamber of the heart) [19].

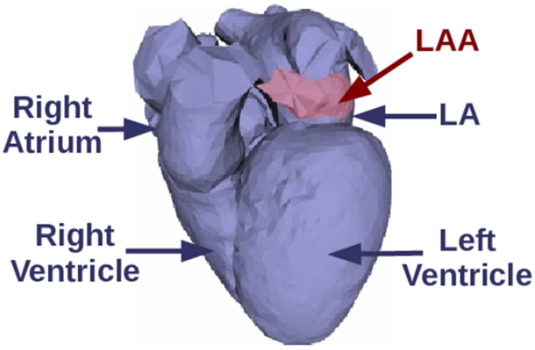

Figure 2. *The anatomy of the heart.*

Due to special anatomical of LAA, which is the main body of thrombosis (Figure 3) and these thrombi usually, attach to the ridge between the LAA and the left superior pulmonary vein (LSPV) [12, 20]. When a patient has atrial fibrillation, the electrical impulses that control the heartbeat do not travel in an orderly fashion through the heart. Instead, many impulses begin at the same time and spread through the atria [21]. The fast and chaotic impulses do not give the atria time to contract and/or effectively squeeze blood into the ventricles. Because LAA is a little pouch, it collects blood and can cause clotting in LAA and atria. When blood clots are pumped from the heart, they can cause a stroke [22, 23].

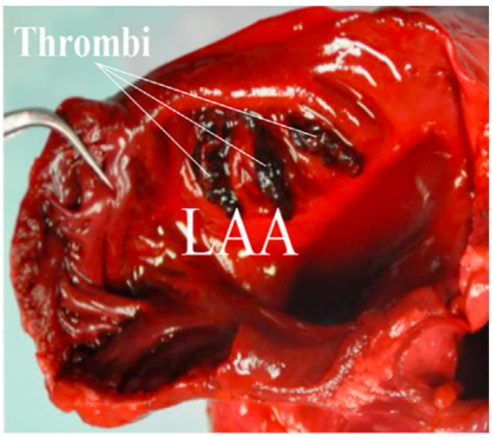

Figure 3. *The LAA thrombi.*

3. WATCHMAN Device Implantation Procedure

Before the procedure, patients received clopidogrel and acetylsalicylic acid (ASA) for at least 15 days before the procedure [24].

There are several options and devices available for closure of the LAA such as AMULET and WATCHMAN devices, which we used of WATCHMAN device that it is a generally safe and feasible method for percutaneously sealing the LAA. The WATCHMAN device is a parachute-shaped, self-expanding device that closes the LAA (Figure 4). It was tested in several studies that showed the device was a good alternative treatment for patients who cannot tolerate treatment with warfarin or are at risk of stroke [25]. It is currently available in five sizes (21, 24, 27, 30, and 33 mm) and allows the occlusion of LAA measuring up to 31 mm in diameter. Closure of the LAA with WATCHMAN as a substitute for long-term anticoagulant treatment for patients with procedural risks is our main goal. This surgery is done through implanted in LAA to reduce the risk of thrombosis, so that blood is not flowing between the LA and the LAA [26, 27].

Table 1. *WATCHMAN device.*

Maximum LAA Ostium (mm)	Watchman, Device Size (mm) (uncompressed diameter)
17-19	21
20-22	24
23-25	27
26-28	30
29-31	33

The WATCHMAN device is implanted percutaneously (through the skin) in the electrophysiology (EP) lab. By closing the LAA, the risk of stroke may decrease and over time, patients may be able to stop taking anticoagulant drugs. In this process to determining exact size for LAAC used the table (Table 1) provided by the manufacturer. In summary, it is important to have a precise understanding and detail of the structure and surface of LAA for these surgeries [28, 29].

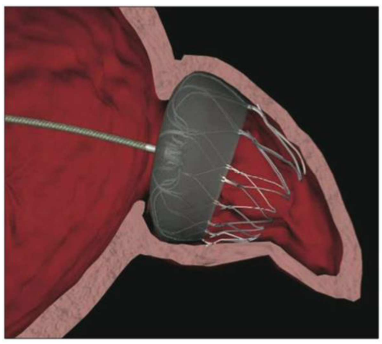

Figure 4. *The LAA closure device.*

4. Method

The improvement of modern medical imaging provides us many suitable conditions for the study of the LAA and the treatment of thrombosis. Echocardiography (Echo) and computed tomography (CT) are commonly used methods to have a grasp of the LAA anatomy and are greatly useful for physicians [30]. In this task, Echo was used which is one of the most advanced medical imaging diagnosis tools. On the other hand, examination LAA only based on echo data for surgery cannot be very detailed. Thus, there is an urgent need for a new approach to the accurate diagnosis of the LAA. Since the LAA is not primarily circular, measure the depth, shape, size of the LAA lobes, as well as distance between the LSPV and the LAA, are complicated. Therefore, it is necessary to have multiple two-dimensional cutaways at different angles, which can be evaluated with the smallest and largest size of the LAA [31-32].

An easier way that used in this task is to transfer one three-dimensional image into three two-dimensional. With respect to Figure 5, one three-dimensional image of the LA is taken by echo, and then the corresponding software gives us three two-dimensional images. So, transferred natural scene to each 2-D LAA slice.

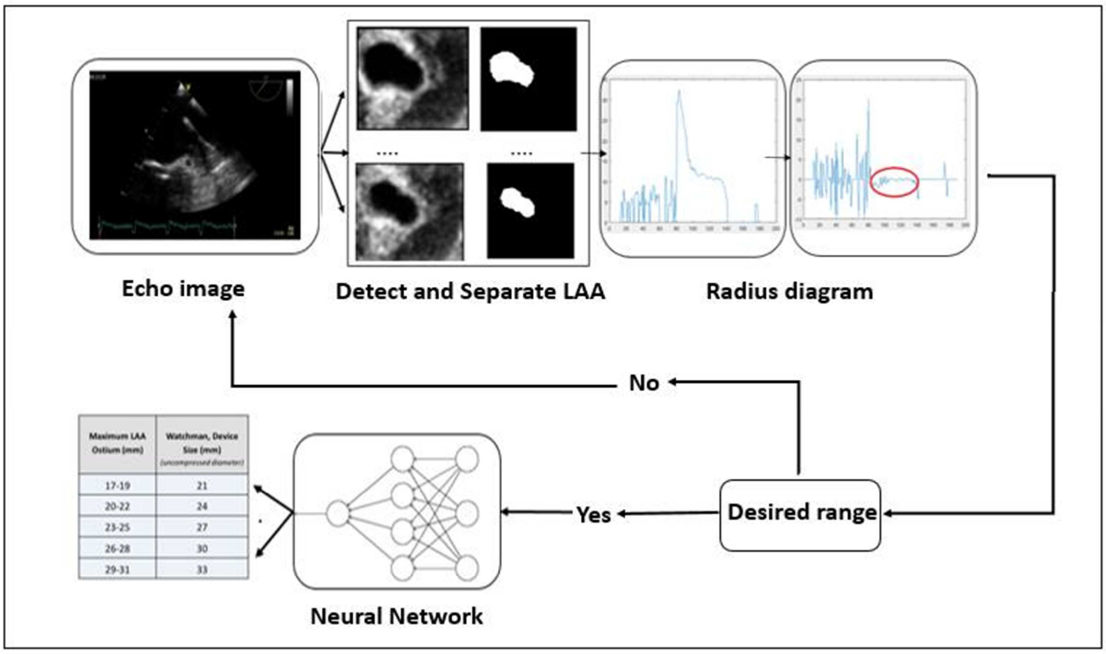

Figure 5. *The algorithm of the LAA.*

In this study Gaussian blur and contrast resolution were used as filters in image processing.

The Gaussian blur, also known as Gaussian smoothing, is the result of blurring an image by a Gaussian function. This is a widespread effect on graphics software, typically to reduce the detail and noise of images. Contrast resolution is the ability to detect intensity differences in an image. This measurement is used in medical imaging to quantify the quality of the images obtained.

According to Figure 5 and table 1, the aim of this process is to find the best size for LAAC with Watchman; so first, the initial processing should be done on different types of echo images to identify the LAA. Thus, the images include LAA would be saved and then has to detected and separated LAA from the image which is done using filters such as Gaussian blur. Third, the diameters of the LAA is calculated as a diagram of the changes in the diameters. In the next step, smallest and largest size of the LAA are calculated based on the diameters plot. So that, length, shape, and size of the LAA will be considered. It should be noted that in examining the images, we face some challenges, such as the presence of a large pectin muscle, which may sometimes be confused with LAA or many small lobes in LAA. Therefore, these three steps are considerably enhanced to improve the accuracy of the LAA diagnosis.

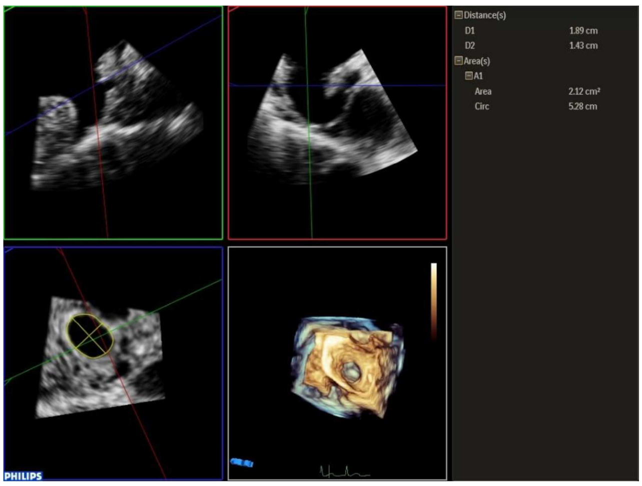

Figure 6. *Echocardiographic image of the left atrium.*

After these steps mentioned above and with respect to Figure 6, the spatial information of images such as the long and short diameters of the LAA (D1 and D2), area (A1), and size of the LAA lobes are saved. If the D1 and D2 are not within the desired range or the program can not calculate the diameters, the system must be returned and the process continues on the next image.

In general, for successful NN training, we need many samples. In this study, we used more than 6,000 images in our data set to obtain sufficient training data. Finally, in order to select the Watchman device size from table 1, the analysis is performed on data stored by the Neural Network to identify the best and most appropriate size for the LAAC. Auto-diagnosis of LAA and device therapy (LAAC) can facilitate to treat AFib [33].

As we can see in Figure 7, working with the program is very simple and User-friendly. You just have to select the images and then all the steps until the selection LAA size for the implant is done very quickly, accurately and automatically.

In this experiment, the program has selected the best size for the implant after preprocessed 210 images from a patient in the first stage. The information panel section contains the number of processed images, the processing time for each image and the total time of the process for all images which saved. In the object selection, we have the number of images transmitted and saved from the three steps we've already described, in this case 6 images stored. The information on these images is analyzed by the NN that has previously been trained. Finally, according to the result, maximum LAA Watchman, size 21 for LAAC is selected.

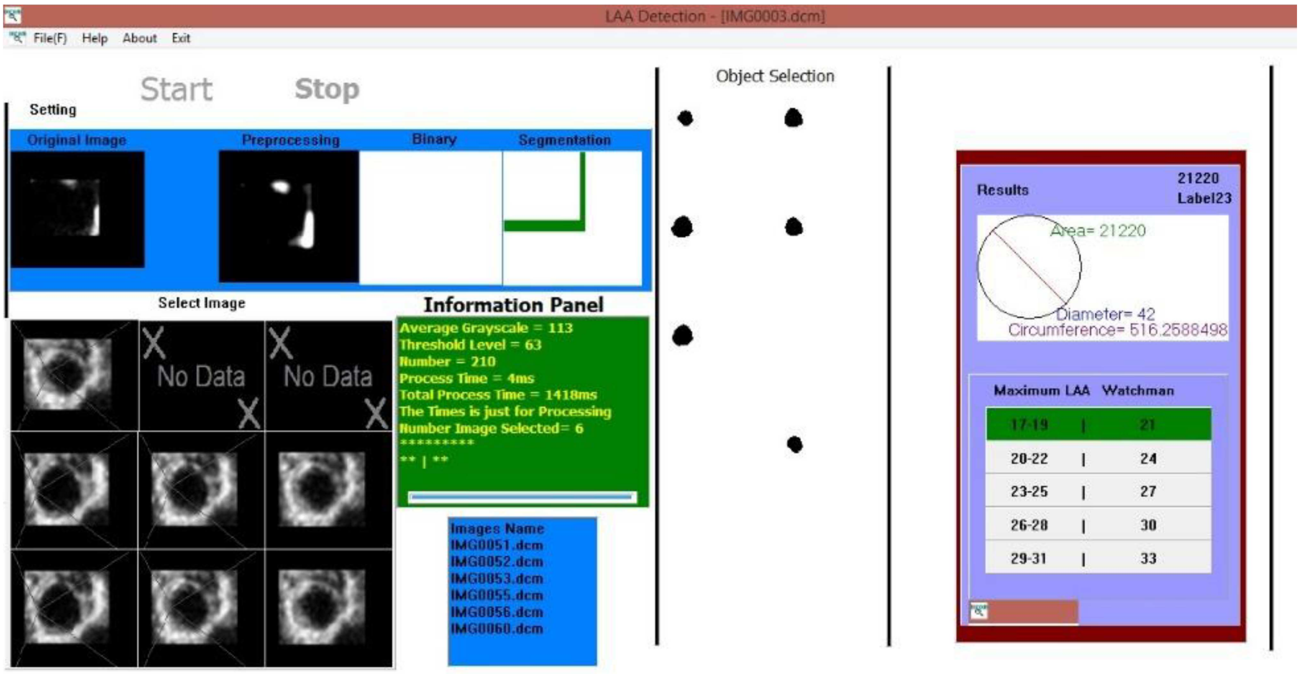

Figure 7. Results.

It should be noted, that whole process is completely automatic.

5. Conclusion

The LAA is the most common place for the clotting that causes a stroke. The proposed approach can quickly and robustly an auto diagnostics of Left atrial appendage to achieve Left atrial appendage closure. The LAA is a complex structure. The irregular anatomy of the LAA with many small lobes that their borders are usually unclear on echo, as well as exist large pectin muscles in images that may be confused with LAA, requires a multi parameter approach and new techniques for the measurement and detection of LAA for device therapy, which is included in our program. The Gaussian blur and contrast resolution filters as well as Neural Networks (NNs) are used to improve medical image analysis and get the best results. Multiplane two-dimensional and three-dimensional echocardiographic information and NN are useful to identify LAA and the catheter size needed to closure of left atrial appendage. In summary, we are trying to create an automatic positioning algorithm from LAA in 2-D images with Delphi.

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