CHAPTER 2

Literature Reviews and Related Literature

This chapter provides an overview of basic knowledge of ultrasound physics, ultrasound scanning of fetal heart, cardiomegaly, Hemoglobin Bart's disease and related literature.

2.1 Basic Knowledge of Ultrasound Physics

Ultrasound is an oscillating sound pressure wave with a frequency greater than the upper hearing limit of the human hearing range, which is generally over 20 kHz. In general, medical ultrasound devices usually use much higher frequencies, in the range between 2-15 MHz [5]. For example, pregnancy scanning is performed around 3-7 MHz [6].

To produce an ultrasound, an electrical current is alternately applied across a piezoelectric crystal which was made from ceramics such as barium titanate and lead zirconate (PZT). The piezoelectric crystal grows and shrinks depending on the voltages running through it. Such high speed vibration consequently produces an ultrasound. This conversion of electrical to mechanical energy is known as the piezoelectric effect as shown in figure 2.1 and 2.2. The generated sound further propagates and then reflects off the object under investigation. The sound later returns and hits the piezoelectric crystal causing the reverse effect – the mechanical energy production. The sound vibrates the crystal and the electrical energy is generated. By measuring the time lag between the transmitted and received sound, the amplitude of the sound, and the pitch of the sound, a computer can produce images, calculate depths, as well as speeds.

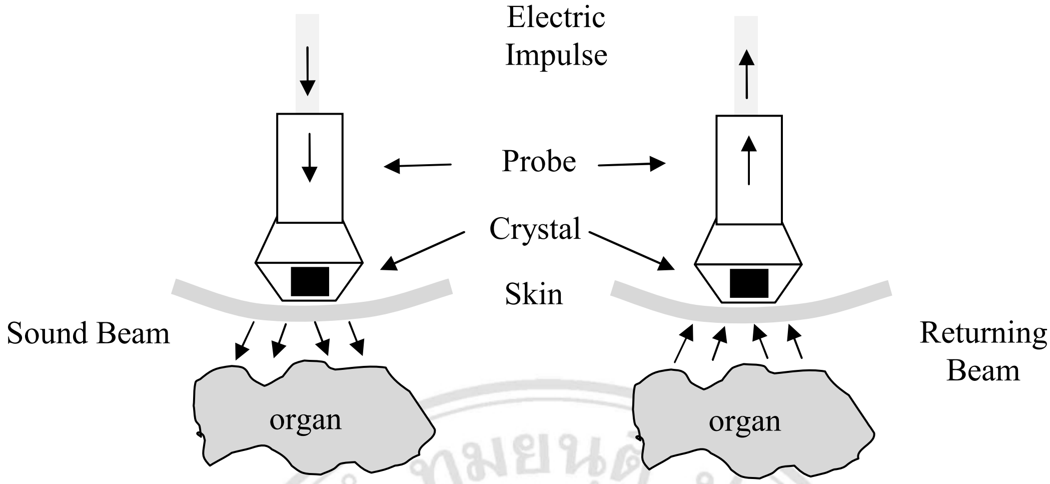

Figure 2.1 Ultrasound device function by changing electrical signals to mechanical vibration and from mechanical vibration to electrical signals.

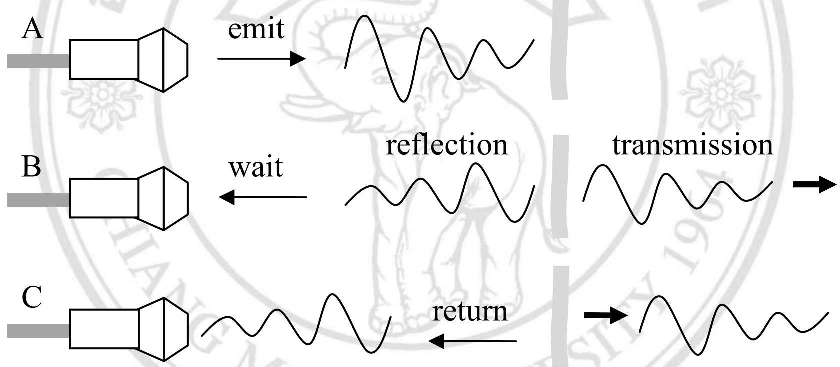

Figure 2.2 Traveling of wave in human tissues.

2.1.1 Image Creation

Sound waves are transmitted from an ultrasound probe through human tissues including bones and muscles of various organs. Some of them can penetrate all the tissues while some disperse and reflect back to the receiver, called transducer, to create an image on the ultrasound screen. Each type of tissues absorbs or reflects different sounds depending on its density [5]. The sound waves reflect more on solid parts. Fluids (like blood) transmit ultrasound waves and have minimum waves reflected back or the black image shown on the ultrasound screen if the entire sound wave scan goes through human tissues. The white bright image occurs when the waves reflect bones and stones. Whenever all the waves are absorbed or reflected by the tissues, they will obscure the image of the deeper organ as shown in figure 2.3[6].

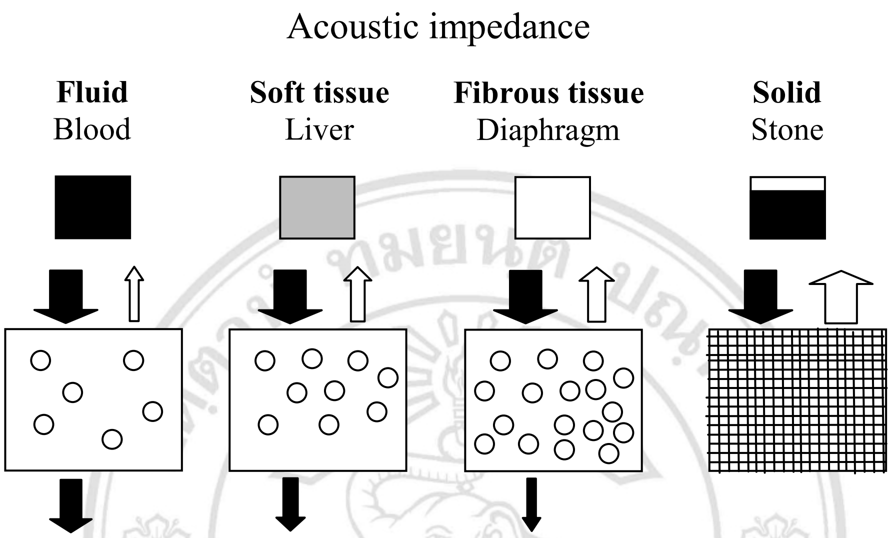

Figure 2.3 Acoustic impedance reflex from different density of objects.

2.2 Ultrasound Scanning of Fetus Heart

Ultrasound scanning used to detect abnormality of fetal heart could be done at the second trimester but the best time to practice is during the 18-20th weeks of pregnancy.

Many heart planes, as shown in figure 2.4, are used in the examination of fetal heart abnormality. Four chamber view (FCV) as shown in figure 2.4 and 2.5, is the main plane needed to be seen in the first place. With this plane, the medical examiner can detect abnormalities of the heart. The accuracy of abnormality detection is 63-96% based on the expertise of the physicians [6].

Key components of a normal four-chamber view include an intact interventricular septum and atrial septum primum. There is no disproportion between the left (LV) and right (RV) ventricles. A moderator band, as shown in figure 2.5, helps identify the morphologic right ventricle.

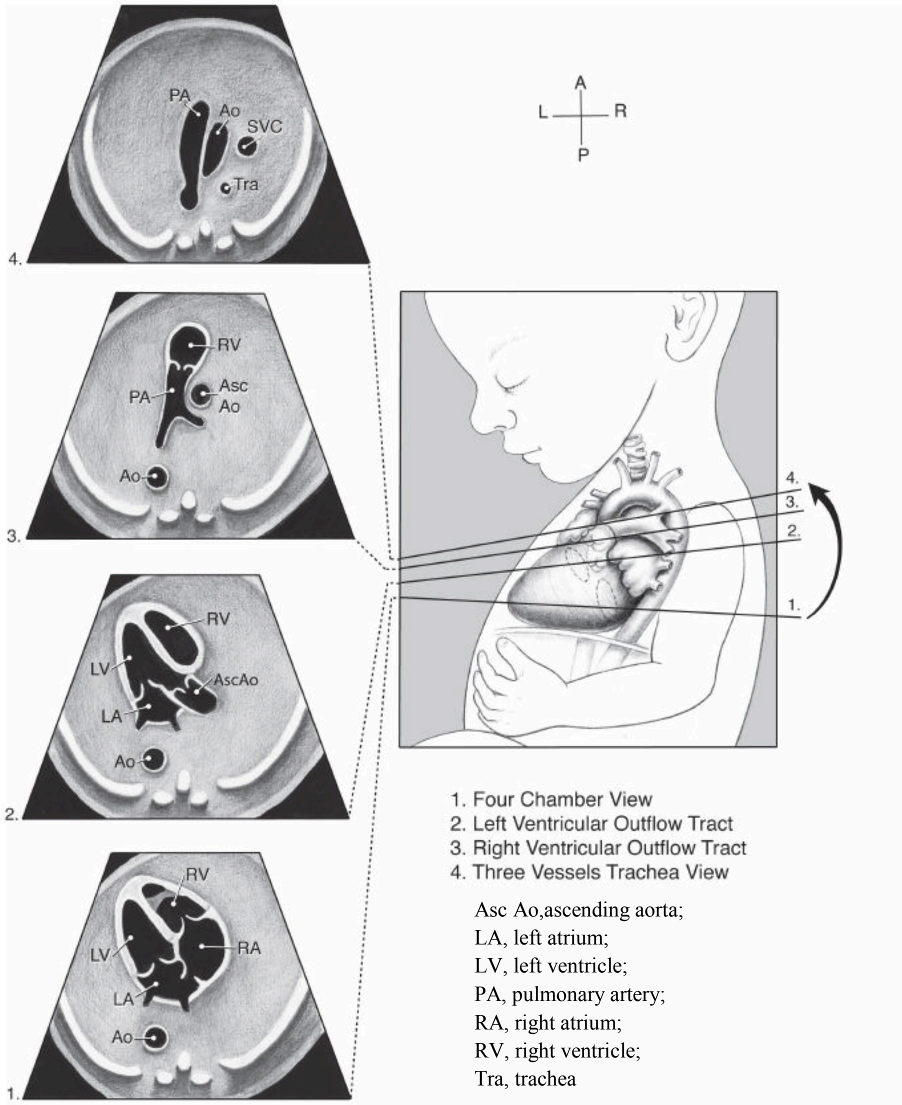

Figure 2.4 Standardized transverse scanning planes for fetal echocardiography. [7]

The criteria used by experienced physicians to indicate a four-chamber view image as shown in figure 2.5, before disease diagnosis are as follows: [6]

1. Clear appearance of the position of the spinal cord
2. Descending aorta line on the spinal cord
3. Sternum being in the opposite side of the spinal cord
4. Right ventricle being close to the sternum
5. Moderator band being close to the apex of right ventricle

The abnormality of heart can be determined based on the ratio of heart (cardiac diameter (Cd)) and chest diameters (transverse diameter (Td)) at four chamber view stage.

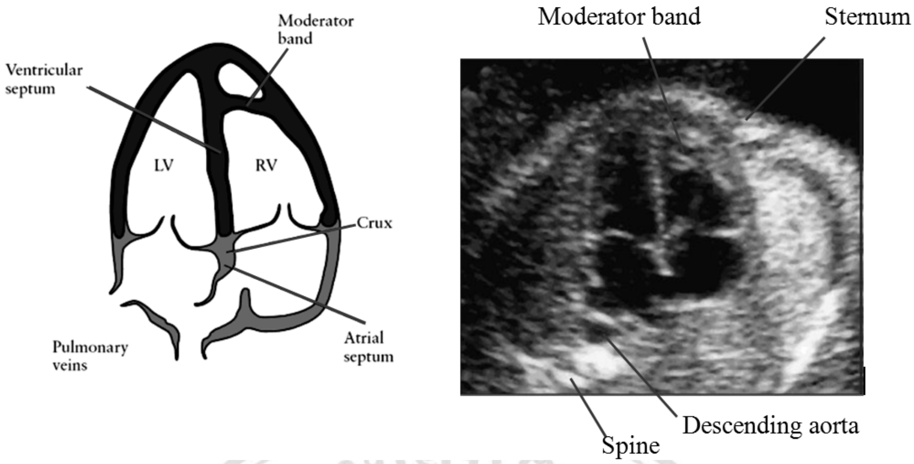

Figure 2.5 Four-chamber view of the fetal heart. [8]

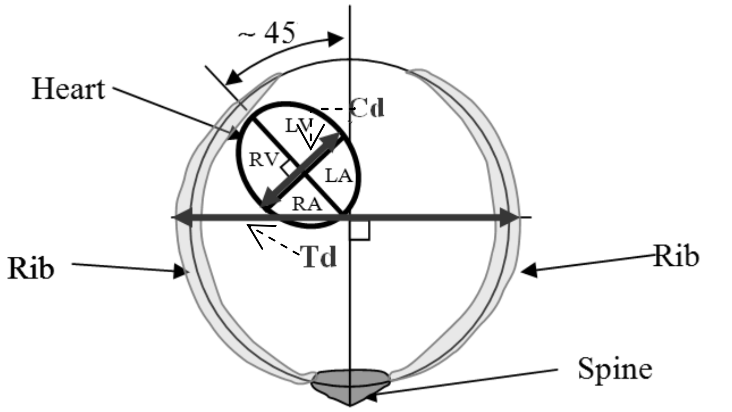

Figure 2.6 Four-chamber view (FCV) of a normal fetus heart showing the positions of cardiac diameter (Cd), and transverse diameter (Td).

Cardiac diameter (Cd) is commonly measured at AV valves level during end-diastole and compared with the normal value of 14-40 weeks fetus [6]. Transverse diameter (Td) is the biggest line measured between the outer edges of left and right ribs. The measurement line should be perpendicular to the line from spinal cord and sternum as shown in figure 2.6.

The cardiothoracic ratio is the ratio of the size of the heart to the area within the rib cage. CT ratio is the ratio of cardiac diameter to transverse diameter:

$$CTratio = \frac{Cd}{Td} \tag{2.1}$$

In general, the manual operations of CT ratio measurement by physicians are as following:

1. Adjust 2D real time scanning equipment to receive a proper FCV when the whole ribs and pulmonary vein are clearly seen.
2. Move the picture frame in cine loop until end-diastole is reached or until the biggest values of both ventricles are observed. Then freeze the frame.
3. Draw a line between the middle of spinal cord and the middle of sternum.
4. Then draw a line across the widest chest chamber in perpendicular to the previous line to get “Thoracic diameter”.
5. Draw interventricular septum (IVS) line and divide it equally.
6. Draw a line through the largest area of the heart in perpendicular to the IVS line (normally a bit lower than AV valve). It is a cardiac diameter.
7. Calculate the ratio of cardiac diameter to thoracic diameter (CT ratio).

Tongsong T. and Tatiyapornkul T. [1] performed the total of 238 cases of CT ratio measurements on healthy fetus. The mean CT ratio value increases from 0.38 at 11 weeks to 0.45 at 20 weeks .The mean of CT ratio value at each gestational week is less than 0.50 and no fetus had a CT ratio greater than 0.50 at 11-15 weeks of gestation. Therefore, in this experiment, CT ratio which is greater than 0.50 will be used to indicate cardiomegaly.

2.3 Cardiomegaly [9]

Cardiomegaly is a general term used to describe any conditions that cause an abnormal enlargement of the heart. Generally cardiomegaly is indicated when the CT ratio is over 0.50. Cardiomegaly can be caused by a number of different conditions, including diseases of the heart muscle or heart valves, high blood pressure, arrhythmias, and pulmonary hypertension. Cardiomegaly can also sometimes accompany longstanding anemia and thyroid diseases, among other conditions. Infiltrative diseases of the heart, infections, nutritional deficiencies, toxins (such as alcohol or drugs), and some medications have been associated with cardiomegaly. In some situations (for example, pregnancy), there can be a temporary increased demand on the heart, resulting in some temporary enlargement.

It is important to remember that an enlarged heart is not a disease itself but a physical sign that can accompany many diseases and conditions.

Cardiomegaly in fetus is also referred as an enlargement of fetal heart. It can indicate many diseases, especially hemoglobin Bart's disease which is the most dangerous thalassemia found in Thailand. [5]

2.4 Hemoglobin Bart's Disease

Hemoglobin (Hb) Bart's disease or homozygous alpha-thalassemia1 is the most common cause of hydrops fetalis in South East Asia. The incidence of the disease in this region is approximately between 1/2,000 and 1/200 births. In Thailand at Maharaj Nakorn Chiang Mai Hospital, this incidence is 1/450 births [6]. The disease currently increases in other parts of the world because of people migrations. In the area of high prevalence, prenatal control is commonly performed to avoid serious maternal complications secondary to hydrops fetalis. The disease is usually diagnosed by using ultrasound at the 22th to 28th week of gestation. However pregnancies can be suspected earlier in the at-risk group of this disease at the 13th to 14th week of gestation when placental thickness and cardiothoracic ratio increase. Ultrasound screening is an essential part of early prenatal diagnosis for Hb Bart's disease before the development of hydropic changes or maternal complications [6]. In the case of ultrasound markers, cardiac diameter to thoracic diameter CT ratio is the most accurate value in predicting the fetal disease. [3]

2.5 Related literature

There are some research studies on cardiomegaly detection. However, very few of them are on fetus. Peerachet Porkaew et al. [10] developed an algorithm to automatically determine cardiac and transverse diameters from ultrasound images. A fuzzy-patch labeling image of each ultrasound image was achieved by using the fuzzy C-means clustering (FCM). Two ribs were detected based on the labeled images. They designed a technique which is the summation of difference to segment the heart. The transverse and cardiac diameters were measured regarding detected ribs and heart, respectively. The result of the experiment was 75% correct detection from only 8 samples. The method used to measure Transverse diameter (Td) was in a different position from the expert. Tantipalakorn Chanyarak,[11] developed an algorithm to detect fetal cardiac size leading to intrauterine diagnosis of fetal cardiomegaly. This study analyzed the low quality ultrasound video to identify the border of the fetal chest. Fuzzy-rule based was applied to determine the area of fetal heart. The cardiothoracic ratio is calculated and compared with expert result. The weak point of this study is both cardiac and thoracic diameters are measured from two biggest areas without fixing the position. They intended to use fuzzy-rule based to locate heart position by looking for dark areas of heart chambers in between left and right ribs. However, the dark area within the chest was possibly not the heart chamber. As a result, this method perhaps misplaced the heart chamber.

Some of the published papers have focused on semi-automatic algorithms to determine fetal heart structure in the first trimester. Most algorithms need pre-processing methods either by human or machine. Dindoyal et al., [12] improved the level set algorithm by using the shape prior to segmenting and separating the four chambers of the fetal heart. It is an effective semi-automated method for the fetal cardiac segmentation. However, it required a specialist to perform the procedure. Deng et al., [4, 13] invented an automatic selection method for getting ROI based on motion summation imaging. Then, noise was despeckled using a Rayleight anisotropic filter. They used an active appearance model (combining the shape and texture models) and an active cardiac model (using both structure and motion information) to detect the heart structure. Jacob et al., [14] reduced the speckle noise by using a median filter and used K-means clustering to obtain the ROI. The heart structure was then detected by using an active appearance model in ROI. Sampath et al., [15] reduce speckle noise by using probabilistic patch based maximum likelihood. Then, seed points were manually selected for segmenting the heart structure by fuzzy connectedness based image segmentation.

Another related research work was published by Theera-Umpon N., [16]. He proposed a technique to segment single cell images of white blood cells in bone marrow into two regions, nucleus and non-nucleus. The patch-based fuzzy C-means was introduced by him to over-segmented cell. The results of segmentation were compared to an expert's manually segmented images. The initial investigation of the use of the derived segmented images in the cell classification was also performed by using the Bayes classifier.