Preliminary study of image processing techniques for the detection of varicocele based on 2D ultrasound images

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Abstract. Varicocele is quite common among male population but can only be confirmed and treated through surgery which may affect the fertility. While ultrasound (color Doppler technique) can be used to diagnose the varicocele, the need to perform the Valsalva maneuver technique when performing the color Doppler ultrasound scanning might make patient become uncomfortable. Therefore, this preliminary study has been done to see whether any image processing techniques can be used to enhance the 2D ultrasound image to help the diagnosis. The purpose of this study is to enhance the ultrasound image of 2D varicocele testicle by using image enhancement and edge detection. The images used are the retrospective images of the normal testicle, and testicle with varicocele and severe varicocele (dilated vein). The image enhancement was done using median filter while the edges were detected using Sobel operator. Based on the analysis, sobel technique does an excellent job to show the varicocele region especially the dilated vein. To summarise, further image processing methods could be applied using different image processing techniques as the analysis could be helpful in giving the urologist the second opinion during diagnosis of varicocele before the surgery.

1. Introduction
Varicocele is defined as a scrotal abnormality or swollen because of elongated, dilated and tortuous veins that cause the testicle drain. Usually, varicoceles can occur in 15% among male population, and it might be an evolutionary consequence of men’s upright posture. More than 80% cases of varicocele occur on the left side and the remainder on both sides. Generally they tend to happen during puberty for male population [1].

There are no symptoms for varicocele disease but it can cause uncomfortable condition and scrotal pain. It can happen while sitting for a long period, doing vigorous activity or standing in a wrong way and it could be relieved by lying down. It also could be uncomfortable before sleeping after having a hectic day with full of activities. The pain will go away after resting for the night. Usually, when a person got the pain he will feel just like tooth ache, dull, and congestive but the pain do not spread to other parts of the body [2]. However, a person who gets varicocele pain can hardly aware of it until the scrotal wall become thick and contracted. The most danger for this case is it can be associated with male fertility and there are no urination issue and erectile dysfunction. When the dilated vein becomes
larger, the varicocele could be clumpy and the person could feel like a “bag of worms” in the scrotum and could give uneasy feeling to the person as well [3].

Currently, the best way to confirm and treat varicocele disease is through surgery. This surgery is a minor surgery and patients can leave the hospital on the same day as their surgery took place. During this procedure, patients will receive anesthesia treatment which is several type of numbing medication. Then, the urologist will make a cut at the lower abdomen part then the abnormal veins will be tied off to prevent the blood flow and as the result, the blood will flow into normal veins area. For reducing the swelling, an ice pack is placed on the area by the patient within 24 hours after surgery [4]. However, it is very important to examine and diagnose this disease before doing the surgery to avoid male infertility.

Ultrasound imaging can be used to produce image of a man’s testicles and surrounding tissues. In helping to determine abnormality of the testicles, epididymis and scrotum ultrasound imaging is the main or primary method. Moreover, ultrasound does not use ionizing radiation so it is safe and noninvasive [3]. Color doppler ultrasound (CDUS) is one of the technique that could be used to examine varicose vein [5]. However, the patient needs to perform the Valsalva maneuver technique each time during the diagnosis, thus making the patients feel uncomfortable.

Therefore, this study proposes to use the processing of the 2D ultrasound images, to see whether is it possible to diagnose the varicocele using 2D ultrasound (without the need to perform the Valsalva maneuver as in CDUS) with the help of the pre-processing techniques to those images.

2. Material and Methods
This study uses the 2D ultrasound images of varicocele from the male subjects. The study was performed to the retrospective images thus details on the patients could not be retrieved. Nevertheless, all DICOM images used are still in good condition and the diagnosis of the images has been confirmed and evaluated by specialist. For this study, all images used are roughly in the size of 300x240 before cropping. Figure 1 shows the example of the original images of (a) healthy testicle, (b) varicocele region of the left testicle, (c) testicle that potentially has varicocele and (d) larger dilated vein that shows the severity of the varicocele pain.

![Figure 1. Ultrasound image of; (a) healthy testicle, (b) varicocele region, (c) potential varicocele, (d) larger dilated vein.](image-url)
For this study, general pre-processing techniques were applied to the images as in block diagram in Figure 2; consist of data collection, image cropping, image filtering and edge detection. The data is gathered from a local hospital and categorized into 3 groups for analysis purposes. Group 1 consists of normal testicle for comparison with those with varicocele. Group 2 are the data with the varicocele and Group 3 are those with the severe varicocele (dilated vein).

![Data Collection (Retrospective)](image)

![Image Cropping](image)

![Image Filtering](image)

![Edge Detection](image)

**Figure 2.** Process applied for this study

After gathering all the retrospective data needed, all images were cropped so that only the testicle region would be examined. For images with vericocele, the part that only have those vericocele were selected. The example of the cropped window is as in Figure 3.

![Figure 3. Example of cropped image; (a) original images showing the selected area (red square) and (b) the cropped image](image)

Then, the image filtering was performed using median filter. Median filter is a non-linear filter and is also known as rank filter [6]. Overall, it can reduce the salt and pepper noise and at the same time maintain the sharp edges of the images. The median filter will consider every pixel in the image and based on its nearby pixel, it will decide whether or not it represents the surroundings [9]. The median can be calculated by performing few main steps;
Step 1: Arrange the neighborhoods pixels into the numerical order.
Step 2: Find the middle pixel value.
Step 3: Replace all the neighborhoods pixels value to the middle pixel value.

Based on previous researches, median filter has shown to give a good result with high value of power signal to noise ratio (PSNR), low value of mean squared error (MSE), while still preserving the important edges when using it with ultrasound images [6-9]. Therefore, in this preliminary study, median filter were applied to the images. The example of the result when filtered using the median filter is as in Figure 4. From the figure, it shows that the images has smoother surface as compared to their original versions.

![Figure 4. Result after median filtering for; (a) Group 1, (b) Group 2, (c) Group 3.](image)

Lastly, this study also performs edge detection. Edge detection is a process of finding and locating image edges. Edge detection of an image is a very important step towards understanding image features because edges may contain features that could be significant and meaningful [10]. There are various types of edge detection operators [12], but the one that was chosen for this study is the Sobel operator. This operator measures the 2-D spatial gradient of the image and then emphasizes those regions with the high spatial. This operator has two 3x3 convolution kernels which were 90° to each other. This is important as it can optimize the respond to edges running vertically and horizontally relative to the pixel grid, where one kernel represents a certain orientation and another kernel represents its perpendicular orientation [12]. Sobel operator has been chosen to be applied as it offers two main advantages as below [11]:

1. It has smoothing effect to the random noise in the image because of the average factor introduced in the operator.
2. The edge seems thick and bright as the elements of the edge on both sides have been enhanced (differential of two rows or two columns).

### 3. Result and Analysis
The Sobel technique does its job to show the varicocele region especially the dilated vein. Some observations have been made when performing the Sobel operator to the filtered images. As for healthy testicle in Figure 5, the white spots around the testicles are in sequence shape to indicate no dilated vein. Furthermore, size of the white spot also smaller meaning that the vein in normal condition without any enlargement. There are also no significant size differences between left and right testes for the healthy testicle.
Figure 5. The output of Sobel operator for healthy testicle (Group 1)

For cases with varicocele (Group 2), the white spot coagulate at the testicle. It is shown there is dilated vein and cause the size of the vein increases. The size of the white spot little bit larger than healthy testicle. Then, the present of the dilated vein indicate there is varicocele pain as in Figure 6.

Figure 6. The output of Sobel operator for vericocele testicle (Group 2)

Figure 7 shows the output of Sobel operator for dilated vein (Group 3). The white spots are bigger and coagulated at certain parts. It is shown there is big dilated vein that increase the severity of the varicocele.

Figure 7. The output of Sobel operator for testicle with dilated vein (Group 3)

Based on the result, it can be seen that pro-processing techniques is helpful in enhancing the important features of the 2D ultrasound images. As in the result, we can see that that Group 1 has only few white spots. While as the varicocele become severe, the white spots will become more complicated and coagulated.
4. Conclusion
From this research, the sobel technique shows clearly the dilated vein in the form of white spots. User also could observe the size and condition of the dilated vein. This result can be helpful for urologist to diagnose the severity of varicocele. However, detail testing on different image filtering techniques, and different edge detection could be performed in order to get a better result.

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