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ACCURACY OF PROSTATE VOLUME MEASUREMENT ON 2D TRANSABDOMINAL USG MODALITY USING THE GRADIENT VECTOR FLOW (GVF) SEGMENTATION APPLICATION MEASUREMENT TECHNIQUE

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KEYWORDS

Keywords: Prostate Volume, Transabdominal Ultrasound, Gradient Vector Flow (GVF), Ultrasound Image

ABSTRACT

In the field of radiology, supporting examinations to evaluate the prostate include examination with X-rays, Magnetic Resonance Imaging (MRI), and ultrasonography (USG). Of all imaging examinations that have been carried out throughout the world, it is estimated that around 25% use ultrasound. The general objective of this research is to analyze the design of the Gradient Vector Flow (GVF) segmentation algorithm on 2D ultrasound images to measure prostate volume in the adult age group. This study created a Gradient Vector Flow (GVF) segmentation application for the prostate organ to calculate the prostate volume calculation. RnD research with an experimental approach was carried out by creating a Gradient Vector Flow (GVF) segmentation design application, tested on 15 DICOM-based ultrasound images, measuring and calculating prostate volume using caliper measurement on ultrasound equipment and Gradient Vector Flow segmentation application. Measurements were made by an expert (sonographer) as an observer with data analysis using SPSS statistics. Analysis of ultrasound image of prostate volume using caliper measurement technique and Gradient Vector Flow (GVF) segmentation is similar to a p-value of 0.950 (> 0.05). Measurement with caliper measurements has similarities shown by the mean rank value of Gradient Vector Flow (GVF) of 15.60 with a mean rank value of caliper measurement of 15.40. GVF application measurement on transabdominal ultrasound prostate volume measurement is similar to caliper measurement and can be used to get more accurate results on objects with less clear edge characteristics. However, the caliper measurement method can be used more efficiently.

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INTRODUCTION

In the field of radiology, supporting examinations to evaluate the prostate include examination with X-rays, Magnetic Resonance Imaging (MRI), and ultrasonography (USG) (Soeprijanto, 2017). Of all imaging examinations that have been carried out throughout the world, it is estimated that around 25% use ultrasound (Alam, 2021). This is because using ultrasound modality has several advantages, including ultrasound examination is a non-invasive examination (does not use needles or injections). Ultrasound is a safe examination, the equipment is cheap, and the imaging results are fast. Ultrasound examination is painless and easily tolerated by most patients. Ultrasound is widely available, easy to use, and costs less than the MRI imaging method. Also, imaging with ultrasound modality is very safe and does not use ionizing radiation, which is harmful to the body compared to X-ray (Damanik et al., 2021). This is what causes examination of the prostate organ using ultrasound modality to become more popular compared to MRI. Ultrasound has several other advantages; apart

from being low cost and easy to use, ultrasound can also demonstrate the same capabilities as other modalities, such as MRI and CT, in differentiating tissue class levels (Alam, 2021).

Ultrasound examination of the prostate is usually performed to evaluate the lower abdominal organs (transabdominal ultrasound). It is quite well-accepted as the first modality to show the size of the prostate in various conditions (Djojodimedjo & Sigumonrong, 2016). A prostate ultrasound usually uses various inspection techniques and acoustic windows to increase visibility and improve image quality. In the ultrasound image, the echo pattern structure of the prostate appears more echogenic compared to the texture of the urinary bladder.

Based on the Ministry of Health (2019), the age division in adulthood is divided starting from the age of 26-35 years, which is referred to as early adulthood; the age of 36-45 years is referred to as late adulthood, the early elderly period begins at the age of 46-55 years, the late elderly period is in the age range 56-65 years, and old age begins at the age of 65 years and above. The overall prevalence of an increase in prostate volume size is 10.3%, with an overall annual incidence rate of 15 per 1000 person-years, increasing with age (3 per 1000 at age 45-49 years, to 38 per 1000 at age 75-79 years). For men without symptoms at the age of 46 years, it is 45%. It is important to know that Lower Urinary Tract Syndrome LUTS can present without complaint and can be caused by variations in sympathetic nerve stimulation of prostatic smooth muscle, variability in prostate anatomy, and variable effects on bladder physiology of obstruction and aging. (Lawrentschuk et al., 2021).

The enlargement of the prostate volume that occurs in patients examined using ultrasound modality can be caused by various pathological causes. BPH (Benign Prostate Hyperplasia) is almost ubiquitous in older men, increasing from age 40-45 years, reaching 60% at age 60 and 80% at age 80 (Lerner et al., 2021). (Lerner et al., 2021)can cause benign prostate enlargement and urinary tract obstruction. Apart from that, the prostate ultrasound image's shape looks irregular due to obstruction in the urinary tract (Foo, 2017). This can lead to inaccuracy in measuring organ volume, resulting in inaccurate decisions in selecting medical treatment. This is the main basis for conducting research (Rudiansyah, 2018).

This research has benefits that can be described as follows: In terms of theoretical benefits, this research will contribute to increasing the insight and knowledge of readers in general, as well as the author himself in particular, especially in the application of the Gradient Vector Flow (GVF) segmentation technique to images of the prostate organ with transabdominal 2D ultrasound modality. This research will also be a useful reference for the Semarang Health Polytechnic academic community, especially the Diagnostic Imaging Department, in developing digital image processing methods.

In terms of practical benefits, this research will help understand the effectiveness of the design and use of Gradient Vector Flow (GVF) on prostate ultrasound image quality in a group of adult men. In addition, the results of this study will provide valuable guidance for radiographers and sonographers in determining prostate examination techniques and can be implemented as a prostate ultrasound scanning examination protocol in the next group of adult men. Thus, this research has theoretical value and significant practical implications in the world of health examinations.

This research has the objectives detailed as follows: The general objective of this research is to analyze the design of the Gradient Vector Flow (GVF) segmentation algorithm on 2D ultrasound images to measure prostate volume in the adult age group. Apart from that, this research has more specific objectives: The first objective is to develop a Gradient Vector Flow (GVF) segmentation algorithm design on 2D ultrasound images to calculate prostate volume in the adult age group. The second objective was to measure prostate volume in a group of adult men using a 2D ultrasound modality by applying the GVF algorithm. The third objective was to compare the results of prostate

volume measurements in a group of adult men using 2D imaging modalities with the results obtained using the GVF snakes segmentation device.

METHOD

This research is a Research and Development study (R&D) that focuses on creating and testing designs for GVF (Gradient et al.) based segmentation program applications to quickly and precisely calculate prostate volume. This R&D research design is expected to produce products and test their performance, in this case in the form of a Gradient Vector Flow (GVF) segmentation application in the prostate organ. The data collection method is carried out directly (prospectively), and the prostate image is taken from data on the ultrasound machine in the form of DICOM data. The population in this study was ultrasound images of the prostate organ MMN Hospital Bekasi and PT MMS clinic, whereas population affordable is the entire population target Which fulfills criteria inclusion. Research uses a numerical measurement scale in one paired group. It is said to be paired because the data is measured twice on the same individual or sample. The sample selection method in this research is included in the sample selection group non-probability sampling, using a convenient sampling technique where the researcher takes samples research based on existing sampling with objective considerations and practically appropriate desired research objectives.

RESULTS AND DISCUSSION

This study's results show similarities in measuring prostate volume using the manual caliper measurement technique with the Gradient Vector Flow (GVF) segmentation technique using lower abdominal ultrasound patient subjects. This research was conducted on DICOM ultrasound images from June to July 2023 at hospitals and clinics in Bekasi, and then the prostate volume was measured using the manual caliper measurement technique on the Mindray 2D transabdominal ultrasound modality. On the same image, measurements were also carried out using the Gradient Vector Flow (GVF) segmentation technique with Mathlab as the software using 15 lower abdominal ultrasound patient subjects. Image taking and measurements were carried out by three experts (sonographers) as observers who worked in the Radiology Unit for nine years, five years, and three years, respectively. Data collection by observers on patients undergoing lower abdominal ultrasound using routine protocols without modification, including taking transverse/ axial, longitudinal/sagittal, and craniocaudal images. For the measurement method with the application, transverse scanning is made in 1 image plane, and two image cuts follow the scanning movement of the prostate organ for image segmentation purposes.

Segmentation design analysis with GVF

The image segmentation process is a stage in image analysis where the main goal is to separate or partition images into groups with the same characteristics or attributes. In this context, segmentation is carried out to separate certain objects of interest from the background or other objects in the image.

This automatic segmentation process of ultrasound images has its uniqueness in its creation, and this can be caused by, among other things, because ultrasound images produce a lower contrast appearance when compared to X-ray, CT-Scan, and MRI images. Other challenges include artifacts in ultrasound images, low gray level variations, and unclear object contours. In some literature, it is also stated that the ultrasound modality is operator-dependent, meaning that anyone who operates the ultrasound device needs to have a good mastery of scanning techniques, anatomy, and pathology. To display a good ultrasound image of the prostate organ requires good patient preparation (full blast) and focus parameters, proper depth, and dynamic range.

The author has not found any research on the topic of ultrasound image volume segmentation; the only research available is the segmentation method aimed at determining the area of the kidney organ, liver mass, knowing the flow of blood vessels, and the area of the prostate organ with a transrectal transducer.

Gradient Vector Flow (GVF) is a segmentation method used in image processing to identify object boundaries or areas with high contrast. This method is based on a gradient vector flow generated from the image.

The following are some important points regarding GVF segmentation.

1. GVF Segmentation applies the GVF segmentation method to prostate ultrasound images to produce precise contours or boundaries. This segmentation helps separate the prostate area from the surrounding structures or tissues.
2. Region-of-Interest (ROI): Select a relevant area or region-of-interest (ROI) that covers the entire prostate in the image segmented with GVF.
3. Gradient Vector Flow: GVF generates a gradient vector flow using gradient information from the image. This flow describes the direction in which the image intensity changes rapidly. This helps determine the boundaries of objects in the image that may be less clear or disturbed by other factors such as noise or texture.
4. Solving Differential Equations: The GVF method involves solving partial differential equations to produce a gradient vector flow. In this process, the gradient vector is obtained by offsetting the local components and the non-linear integral of the gradient vector.
5. External Energy: GVF utilizes external energy associated with the line or contour of interest. This energy can be determined based on gradient strength measurements or other methods, such as feature mapping.
6. Pulling and Blocking: GVF gradient vector flow functions to pull contours into areas of high intensity and maintain the relative distance between contours so that objects remain well segmented. An energy barrier can sometimes prevent the contour from moving into undesired areas.
7. Optimization: GVF applies an optimization process to produce accurate segmentation results. This method involves iteration to update the flow gradient vector based on external energy. Changes in the flow gradient vector are calculated until convergence to achieve stable segmentation.

Accuracy analysis of caliper method measurement test results and GVF segmentation applications

The results of descriptive statistical tests shown by SPSS show that in the group of ultrasound images measured using caliper measurements, the average value was 14.8813, while in the Gradient Vector Flow (GVF) segmentation application, it was 15.1375. The middle value (median) in the ultrasound image group with caliper measurements was 13.4800, while in the Gradient Vector Flow (GVF) segmentation application group, it was 13.7500. The standard deviation obtained in the ultrasound image group with caliper measurements was 38.859, while in the Gradient Vector Flow (GVF) segmentation application group, it was 42.376.

From the caliper measurement data, it can be stated that the lowest prostate volume value in the caliper measurement was in the subject with the initials NN8 with a volume value of 9.7900; The highest score was in the subject with the initials NN5 with a volume value of 22.3400.

From the data above, it can be stated that the lowest prostate volume value in the Gradient Vector Flow (GVF) segmentation method measurement was in the subject with the initials NN8 with

a volume value of 9.7951; The highest scores were for subjects with the initials NN5 and NN6 with a volume value of 23.1664.

Based on research a normal prostate in adults is under 20 cm3. Pathology Prostate hyperplasia increases incidence by 20% in men over 40, reaching 50% in men over 50 and 70% in men over 60 (Biddulth, n.d.). According to the data above, patient subjects with the initials NN5 NN6 have above-average prostate volumes and are over 40 years old. NN5 is 53 years old, and NN6 is 70 years old.

The criteria for taking a good transabdominal ultrasound image of the prostate is if the urinary bladder is filled with approximately 400ml of water (Biddulth, n.d.). To get prostate volume measurement results using caliper measurement: 1) select the distance tool in the measure view menu and start *measuring* by how to draw a vertical line from one edge to another in the area containing information on the prostate organ to obtain the dist1 size (ap diameter or p dimension); 2) then draw a straight horizontal line from one edge to the other to obtain the size dist2 (lateral diameter or dimension l); 3) move to the layout on the right which displays the results of longitudinal scanning, select the distance tool in the measure view menu and measure by drawing a straight line from one edge to the other obliquely in the area containing prostate volume information so that the size dist3 (diameter) is obtained. Craniocaudal or t dimension); 4) The computer automatically calculates the resulting dimensions of length x width x height on the ultrasound machine multiplied by the constant π/6 or 0.52 to obtain the total volume of the prostate organ. This is by research where organ volume calculations in ultrasound are calculated using an ellipsoid formula or a volume-based measurement.

The steps for measuring and calculating prostate volume using the Gradient Vector Flow (GVF) segmentation technique begin with 1) Click the select folder tool to select the patient's DICOM data; 2). Select two ultrasound images of the prostate organ with maximum image information. 3) Copy the image data folder containing the GVF application software; 4) Open the Matlab application program; 5) Open the GVF snakes application software; 6) Run the program by clicking change folder towards the image data previously saved in the folder; 7). Run the ultrasound image; 8). Make an initiation on the border that shows the prostate organ information. 9). Click in the middle of the initiation site; 10) The computer will automatically calculate and calculate prostate volume organ results.

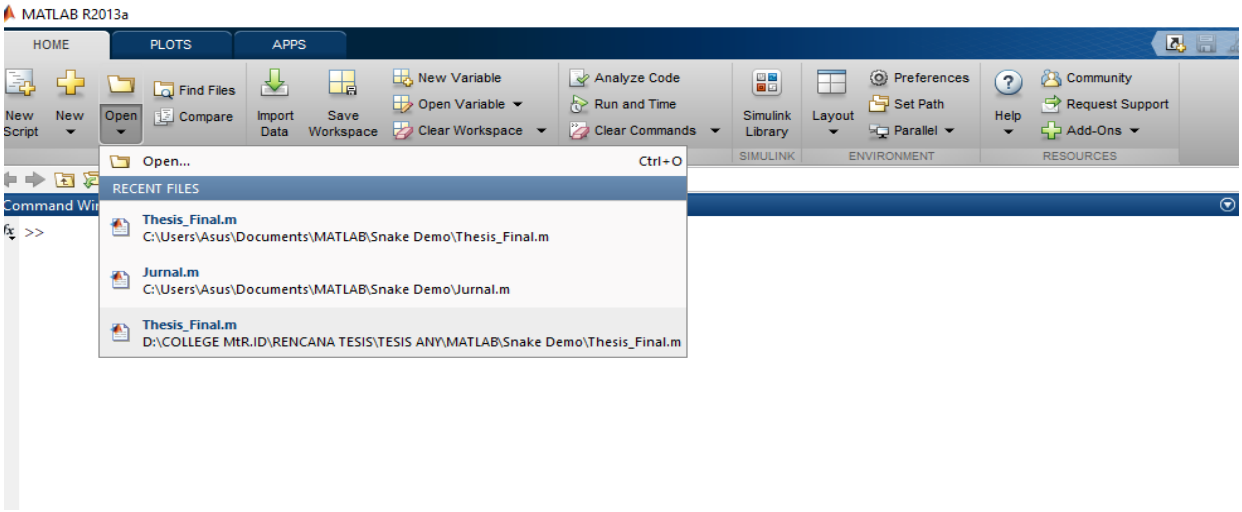

Figure 1 Initial stages of the Matlab file

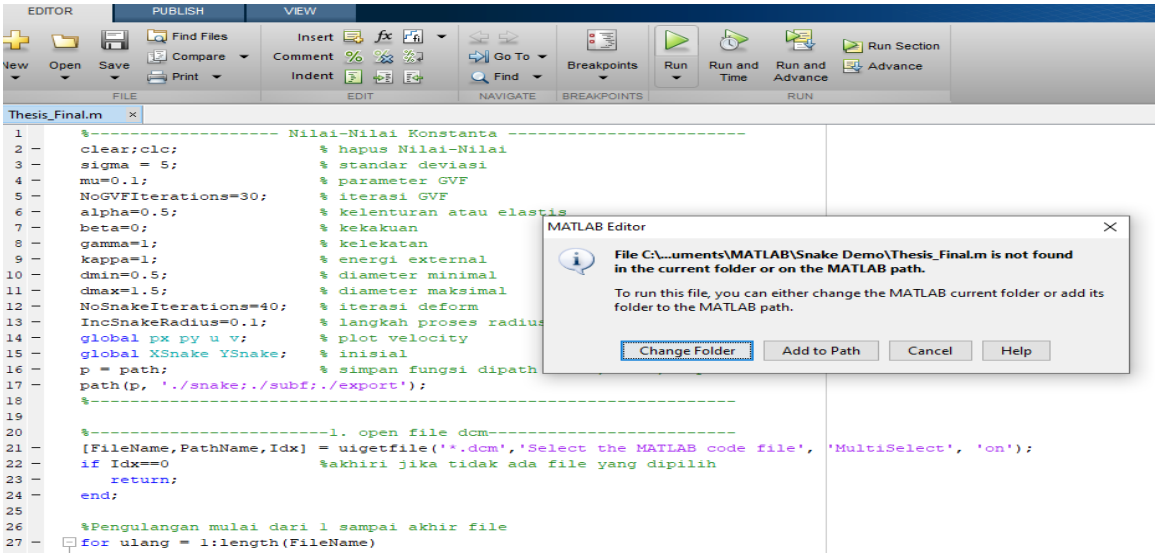

Figure 2 The second stage of the Gradient Vector Flow (GVF) application

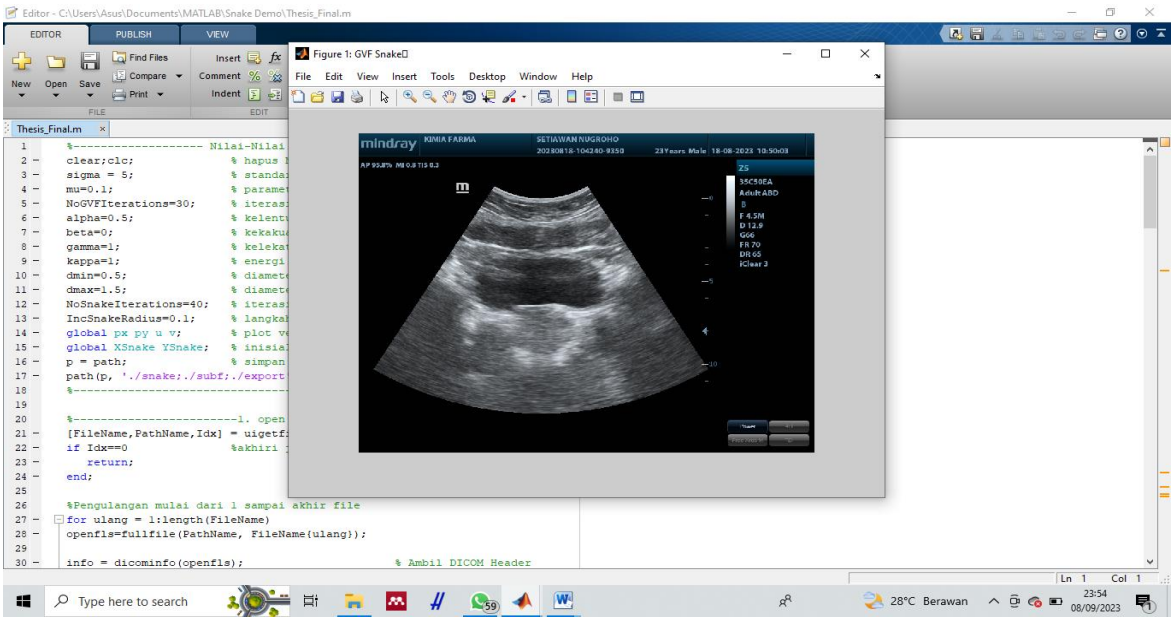

Figure 3 Stage of selecting two images of the prostate organ

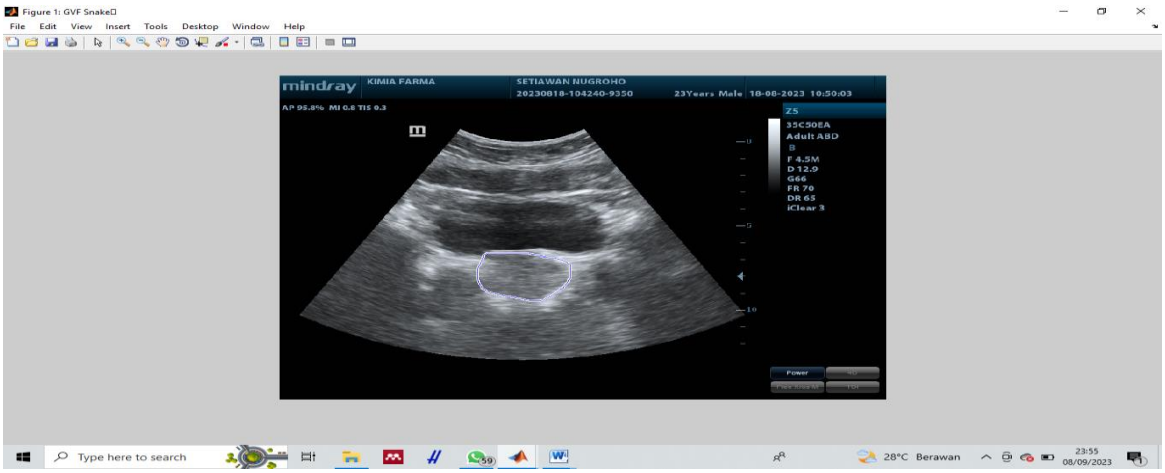

Figure 4 Process of initializing the prostate organ image

Figure 5 Stages of creating an ROI to obtain prostate volume

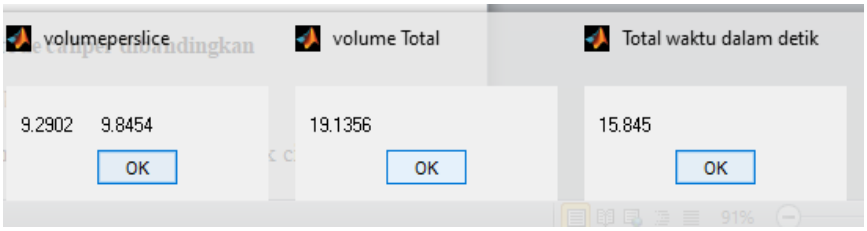

Figure 6 Volume of images 1 and 2, and the total of the two images along with their creation time

Analysis of the accuracy of the caliper method measurement test results compared to the Gradient Vector Flow (GVF) segmentation application

the Mann-Whitney test, which was carried out for information on the group of ultrasound images that were measured with a caliper and the ultrasound images in the group that was measured with the GVF application had an assigned value (p-value) > 0.05, shows that there was no difference in measurements in the two groups. Besides that, the *mean rank values obtained in the caliper and GVF application measurement groups were* 15.40 and 15.60, respectively. *Mean Rank* is the average ranking of each group used in the Mann-Whitney test context, which compares two independent samples. The test results above indicate that the method " Application of the method *GVF* " has a slightly higher *mean rank than the " Caliper measurement* " method. In the context of the Mann-Whitney test, the mean rank reflects the average rank of the data in each group being compared. This shows that statistically, the measurement results in the application have similar results (Yang et al., 2015).

Based on the results of the presentation above, it can be concluded that this research is the same, showing that the measurement of the GVF application, when compared manually in the form of a caliper which is still used so far, the results are similar, thus the conclusion obtained is that this GVF segmentation-based application can be used as an alternative replacement, has good performance. It is good and similar to the results of calculating prostate volume on a 2D ultrasound machine.

The measurement technique using a caliper can get an estimate of prostate volume, often used in clinical practice. However, this method is based on the assumption of approximation of the prostate as an ellipsoid or ellipsoid-like shape. In real conditions, the prostate has a more complex arrangement and shape and is not symmetrical (matthew-hoffman, 2020). Also, the condition of "human error" could occur in the process of taking manual measurements of the plot prostate organ; another possibility besides that is that the ultrasound modality is one of the modalities that are "operator dependent" (Alamelumangai, 2013). The phrase "operator dependent" is used in the medical field to describe how much the knowledge, experience, and ability of the operator performing the examination influences the results or interpretation of the procedure or examination. "Operator dependency" in the ultrasound context refers to the operator's ability and skill to perform the examination, which may

impact the accuracy and quality of the ultrasound images and resulting interpretation (Mamun et al., 2013).

Meanwhile, calculations using the Gradient Vector Flow (GVF) method will potentially have higher accuracy in prostate segmentation because it uses a computational algorithm to identify prostate boundaries more precisely. Meanwhile, the level of segmentation accuracy is influenced by factors such as image quality, segmentation setting parameters, and how the prostate is structured in the image (Zhang et al., 2013).

In calculating prostate volume using the Gradient Vector Flow (GVF) method, it is explained that it uses ultrasound image segmentation of the prostate organ to identify and separate the prostate area from related structures (Li et al., 2016). Ultrasound images generally have diffusion and noise properties, which can interfere with object segmentation. GVF segmentation can help overcome this problem by relying on gradient vector flows obtained from images to identify and maintain precise contours. This helps find object boundaries that are less clear or disturbed by noise in the ultrasound image. After segmentation, the prostate volume is calculated based on the number of voxels included in the prostate segmentation. This method can provide more accurate and detailed segmentation and a more accurate volume estimate. Appropriate (Jazirian et al., 2023).

If the purpose of measuring prostate volume is for a rough measurement or as a general indicator of the prostate organ as a whole, then the measurement method with a caliper could be a solution, but if the purpose of measuring prostate volume requires a higher level of accuracy for clinical purposes or more in-depth research, then this measurement method using the GVF application could be a solution (Zheng et al., 2018).

Author limitations

In conducting research regarding the effectiveness of creating automatic segmentation applications using the GVF method, there are several limitations, some of which are: 1). The research time carried out by the author was limited by the time adjusted to the graduation time so that the prostate organ image data set that could be collected was limited, this had an impact on the amount of image data that was processed. 2) The amount of image data used. The prostate image is a common image found in routine whole abdomen ultrasound examinations; however, collecting image data with the pathology of the prostate, in this case BPH, takes quite a long time. 3). DICOM data is limited. Only ultrasound equipment of certain brands can be processed in the GVF segmentation application, in this case, Matlab. This is because the DICOM numbering information can differ for several ultrasound equipment brands. Not all image formats on the ultrasound machine can be opened with the Matlab application.

CONCLUSION

Based on the research results, the effectiveness of volume measurements using 2D ultrasound techniques with the Gradient Vector Flow (GVF) segmentation application can be drawn as follows: First, the research results show that there is no significant difference in the results of calculating prostate volume between manual measurements and the GVF segmentation method. This indicates that the GVF segmentation method can produce prostate volume data that is not statistically significantly different from manual measurements. Second, the GVF segmentation method applied to prostate ultrasound images can measure prostate volume with results close to manual measurements using a caliper. In this case, the GVF segmentation method has proven to be an effective alternative in calculating prostate volume with high accuracy. Thus, the results of this study indicate that the use of the GVF segmentation method on 2D ultrasound images can provide results comparable to manual measurements and can be considered an effective method for measuring prostate volume accurately.

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