Quantification of Pericardial and Epicardial Fat using ImageJ

N Z Yasmin¹, R S Tohir², P Prajito¹ and D S Soejoko¹,
¹ Department of Physics, Faculty of Mathematics and Natural Science, Universitas Indonesia, Depok, West Java 16424, Indonesia
² Mayapada Hospital Tangerang, Jl. Honoris Raya Kav. 6, Modernkel, Kelapa Indah, Tangerang, Banten 15117, Indonesia
Email: nadia.zakyyah@ui.ac.id

Abstract. Research towards finding new Coronary Artery Disease (CAD) predictors have developed in recent years. One potential CAD predictors are epicardial fat due to its location and function. Another adipose layer of interest is the pericardial fat that is the fat anterior to the epicardial fat. The single slice area method has been developed to estimate volume using a single slice area. In this preliminary study, the aim is to quantify epicardial and pericardial fat using ImageJ and to evaluate the relationship between the fat area and the volume measured. The relationship between the fat parameters, age and gender were evaluated. The samples were cardiac CT images of 50 patients who underwent non-contrast cardiac examination using a 64 CT scanner. ImageJ was used to quantify epicardial and the pericardial fat area and the volume was obtained by the sum of four slices multiplied by the slice thickness. The Pericardial fat area showed a high correlation with the pericardial fat volume (r=0.92, p<0.01) using the single slice area method. Epicardial fat area and volume showed a moderate significant relationship with age. Epicardial volume in female patients was significantly higher than in male patients. Quantification of epicardial and pericardial fat was highly reproducible using ImageJ.

1. Introduction
Coronary artery disease (CAD) is the leading cause of death in the world [1]. Research towards finding new CAD predictors have developed in recent years. One potential CAD predictor is the epicardial fat. Epicardial fat is referred as the layer of adipose tissue that is located between the visceral pericardium and myocardium of the heart [2]. This particular fat has been an interest in many studies due to its location and function that is linked to coronary artery disease (CAD). Epicardial fat is located close to coronary arteries where plaque can occur. Epicardial fat also functions as an endocrine organ that secretes hormones and cytokines that are believed to play a part in the atherosclerosis process [3]. Other cardiac fats have also been evaluated. These adipose tissue layers consist of the paracardial fat, which is the fat outside of the parental pericardium and the pericardial fat, which is anatomically defined as the fat anterior to the epicardial fat between visceral and parietal pericardium. The pericardial fat is also considered as the total sum of epicardial fat and paracardial fat [4].

Quantification of cardiac fat can be performed using different imaging modalities. Echocardiography is a noninvasive method that produces good reproducibility, but is limited only to thickness measurement. Magnetic Resonance Imaging (MRI) is considered as the golden standard for epicardial fat quantification but the images can be prone to artifacts caused by chemical shift [5]. Computed Tomography (CT) is a preferred method for volumetric quantification due to its spatial resolution and high reproducibility [6].
ImageJ as an open source software with user friendly interface makes it a potential software for CT image processing. ImageJ has been used for many medical cases such as thigh skeletal muscle measurement [7], abdominal circumference measurement [8], and lung adenocarcinoma analysis [9]. Quantification of epicardial fat using ImageJ was studied for patients with HIV [10], atrial fibrillation [11], and peritoneal dialysis [12]. However, the quantification of pericardial fat using ImageJ has not been explored.

One area of cardiac fat quantification research is regarding the single slice area method. This study estimated the volume of epicardial fat using an area of a single slice CT found to be correlated best at the Left Coronary Main Artery (LMCA) landmark [13]. This estimation could potentially decrease the time in volumetric CT quantity of fat. The single area method was used in predicting the presence of obstructive coronary artery disease and it resulted in an independent association in respect to the area and total volume [14].

In this preliminary study, the aim is to quantify epicardial and the pericardial fat area and volume using ImageJ and to evaluate the relationship between the fat area using single slice area method and the volume measured. The quantified fat parameters and risk factors of coronary artery disease such as age and gender were evaluated.

2. Material and Method

2.1 Sample preparation
This study consisted of 50 patients who underwent non-contrast cardiac CT scan examination in Mayapada Hospital Tangerang. Cardiac CT scans were performed using a 64-detector row CT scanner, Revolution Evo (General Electronics Healthcare, Milwaukee, WI). The CT images were reconstructed using the following parameters: slice thickness 2.5 mm; tube voltage 120 kV and matrix 512 x512. The determination of the anatomical landmark of the CT images was consulted beforehand with a radiologist.

2.2 Fat quantification
The quantification of epicardial fat and pericardial fat area and volume were performed using ImageJ software (Ver.1.53, National Institutes of Health, Maryland, USA). The flowchart of fat quantification can be seen in Figure 1. The first step is to open the non-contrast CT image. The next step is to delineate the cardiac fat from the heart structure using the ImageJ option Clear Outside in the Edit menu. After obtaining the Region of Interest (ROI), Gaussian filter is applied to the image by using the Gaussian Blur Filter in the Process menu. Gaussian filter is used to reduce the noise of the image [6]. The next step is to segment the fat from the heart structure by thresholding segmentation located in the Image menu and Adjust submenu. The CT attenuation range of fat is between -190 and -30 Hounsfield Unit [3, 6]. In the threshold menu, adjust the lower threshold value to -190 and the upper value to -30 to obtain the fat region. After thresholding, the area of the ROI is selected using Create Selection in the Edit Menu. The last step is to measure the area using the Measure option in the Analyze menu.
2.2.1 Epicardial fat
Epicardial fat area was obtained from a single slice at the LMCA level [10]. It is the adipose tissue within the pericardium. The epicardial fat area quantification was depicted in Figure 2.

![Figure 2. Epicardial fat area quantification: (a) CT image, (b) delineation, (c) gaussian filter, (d) thresholding](https://example.com/figure2)

Epicardial fat volume was obtained from the sum of four slices starting from the upper slice limit of pulmonary artery bifurcation to the apex of the heart [10]. The summed area was then multiplied by the slice thickness [3,15].

2.2.2 Pericardial fat
Pericardial fat area is the overall total fat between the epicardial fat and paracardial fat. The Pericardial fat area was obtained from a single slice at the LMCA level depicted in Figure 3. Pericardial fat volume was obtained from the sum of the 4 area slices multiplied by the slice thickness [16]. The pericardial fat was differentiated using the thresholding segmentation of the fat range from -190 H.U to -30 H.U.
The statistical analyses were carried out using SPSS version 22 (IBM Corp., Armonk, NY, USA). Pearson’s correlation coefficient was calculated to evaluate the relationship between the fat areas in the LMCA level with the total fat volume and the quantified parameters regarding to age. The Kolmogorov-Smirnov test was conducted to determine the normality of the data. The area and volume of the epicardial and pericardial fat were normally distributed. The T-test was performed to analyze the mean difference of the quantified parameters with respect to gender. The p value <0.05 indicates significance. Continuous variables are presented as mean values with standard deviations and categorical variables are presented as frequencies with percentages. Inter-observer reproducibility was examined based on the image processing of two observers who are experienced with CT cardiac images.

3. Results & Discussion

3.1 Patient characteristics
In this study, 50 patients consisted of 27 male patients and 23 female patients with the mean age of 55 ± 9.70 years. The mean values of the fat parameters have also been measured and can be seen in Table 1. The area of epicardial and pericardial fat were converted to cm$^2$ while the volume of both fat is in cm$^3$.

| Characteristics       | Data          |
|-----------------------|---------------|
| Age (years)           | 55 ± 9.70     |
| Male gender n (%)     | 27 (54%)      |
| Epicardial fat area (cm$^2$) | 17.11 ± 7.30 |
| Pericardial fat area (cm$^2$) | 22.05 ± 9.42 |
| Epicardial fat volume (cm$^3$) | 113.20 ± 47.69 |
| Pericardial fat volume (cm$^3$) | 191.95 ± 76.90 |

3.2 Correlation between epicardial fat and pericardial fat area and volume
The correlation of both epicardial fat and pericardial fat areas at the LMCA level and the total volume was evaluated using Pearson’s correlation coefficient. The correlation between the fat measurements are shown in Table 2. The epicardial fat area at LMCA level showed a high correlation (r= 0.89, p<0.001) with the total fat volume of epicardial fat. This result is in agreement with prior studies [13, 14].
The 10th National Physics Seminar (SNF 2021)
Journal of Physics: Conference Series 2019 (2021) 012078 IOP Publishing
doi:10.1088/1742-6596/2019/1/012078

Table 2. Correlation between epicardial and pericardial fat measurement

|                        | Epicardial Fat Area (cm²) | Pericardial Fat Area (cm²) |
|------------------------|----------------------------|----------------------------|
|                        | Pearson rho | p-value | Pearson rho | p-value |
| Epicardial fat volume (cm³) | 0.89         | <0.001   | 0.83         | <0.001   |
| Pericardial fat volume (cm³) | 0.88         | <0.001   | 0.92         | <0.001   |

The pericardial fat area at LMCA level showed a higher correlation to the pericardial total fat volume (r=0.92, p<0.001) than epicardial fat. Although pericardial fat area at this level showed a high correlation with the total pericardial fat volume, further studies regarding the best landmark in estimating the volume should be investigated.

3.3 Relationship between epicardial fat and pericardial fat measurement with age

The relationship between epicardial fat and pericardial fat measurements with age was evaluated. Table 3 showed the Pearson’s correlation coefficient between these variables.

|                        | Age (years) |
|------------------------|-------------|
|                        | Person rho  | p-value |
| Epicardial fat area (cm²) | 0.30        | 0.034   |
| Pericardial fat area (cm²) | 0.24        | 0.101   |
| Epicardial fat volume (cm³) | 0.33        | 0.020   |
| Pericardial fat volume (cm³) | 0.24        | 0.091   |

The epicardial fat area (r=0.30, p=0.034) and epicardial fat volume (r=0.33, p=0.02) showed a moderate and statistically significant relationship with age. This result is in accordance to previously published studies [2, 15]. This is due to the fact that the redistribution of fat tissue occurs during the aging process and is prominent in older women [17]. The pericardial fat area and volume showed no significant value statistically.

3.4 Epicardial and pericardial fat, according to gender

The epicardial fat and pericardial fat measurements were differentiated according to gender, which can be seen in Table 4. Female patients had a higher fat area and volume overall than male patients. There was a significant difference in the epicardial fat volume of female patients (mean volume of 130 ± 53.94 cm³) two male patients (mean volume of 98 ± 36.89 cm³). Previous studies, however reported the opposite in which epicardial fat volume in men tends to be higher than women [16, 17]. Further studies are needed to conclude the impact of gender with regards to epicardial fat.

Table 4. Fat measurements according to gender

|                        | Gender          | Mean Difference | p-value |
|------------------------|-----------------|-----------------|--------|
|                        | Female          | Male            |        |
| Epicardial Fat area (cm²) | 19.02 ± 7.83   | 15.50 ± 6.53   | 3.54   | 0.08   |
| Pericardial Fat area (cm²) | 22.97 ± 9.43   | 21.27 ± 9.51   | 1.69   | 0.53   |
| Epicardial Fat volume (cm³) | 130.00 ± 53.94 | 98.89 ± 36.89  | 31.10  | 0.02   |
| Pericardial Fat volume (cm³) | 196.97 ± 76.95 | 187.67 ± 78.07 | 9.30   | 0.67   |
3.5. Inter-observer Reproducibility

Two observers measured the pericardial fat area of 15 axial slices of CT images located in the LMCA level and manually traced the pericardium of each slice using ImageJ software. The inter-observer correlation for the pericardial fat area resulted in a high correlation ($r = 0.964$, $p<0.01$) and can be seen in Figure 4.

![Figure 4. Inter-observer Reproducibility](image)

4. Conclusion

The Pericardial fat area showed a high correlation with the total pericardial fat volume ($r=0.92$, $p<0.01$) using the single slice area method. However, further studies are needed to determine the best landmark of pericardial fat for volume estimation. Epicardial fat area and volume showed a moderate significant relationship with age. Epicardial volume in female patients was significantly higher than that of male patients. Quantification of epicardial and pericardial fat using ImageJ was highly reproducible ($r = 0.964$, $p<0.01$).

References

[1] M. A. Khan et al., *curious*, vol. 12, no. 7, 2020, doi: 10.7759/cure.us.9349.
[2] R. Khurana, A. Yadav, T. B. S. Buxi, J. P. S. Sawhney, K. S. Rawat, and S. S. Ghuman, *Indian Heart J.*, vol. 70, pp. S140–S145, 2018, doi: 10.1016/j.ihj.2018.08.009.
[3] P. M. Gorter et al., *vol. 197*, pp. 896–903, 2008, doi: 10.1016/j.atherosclerosis.2007.08.016.
[4] G. Milanese et al., *Diagnostic Interv. Radiol.*, vol. 25, no. 1, pp. 35–41, 2019, doi: 10.5152/dir.2018.18037.
[5] R. D. Stoffey, *Am. J. Roentgenol.*, 2010, doi: 10.2214/ajr.10.4249.
[6] G. Coppini, R. Favilla, P. Marraccini, D. Moroni, and G. Pieri, no. July, 2010, doi: 10.2174/1874431101004010126.
[7] D. E. Long et al., *PLoS One*, vol. 14, no. 2, pp. 1–11, 2019, doi: 10.1371/journal.pone.0211629.
[8] S. L. Gomez-Perez et al., *J. Parenter. Enter. Nutr.*, vol. 40, no. 3, pp. 308–318, 2016, doi: 10.1177/0148607115604149.
[9] H. J. Koo et al., *PLoS One*, vol. 12, no. 1, pp. 1–9, 2013, doi: 10.1186/1475-2840-12-127.
[10] M. Sadouni *et al.*, *Eur. J. Radiol. Open*, vol. 8, 2021, doi: 10.1016/j.ejro.2020.100317.
[11] M. Vroomen *et al.*, *Eur. J. Cardio-thoracic Surg.*, vol. 56, no. 1, pp. 79–86, 2019, doi: 10.1093/ejcts/ezy472.
[12] H. H. Lin, J. K. Lee, C. Y. Yang, Y. C. Lien, J. W. Huang, and C. K. Wu, *Cardiovasc. Diabetol.*, vol. 12, no. 1, pp. 1–9, 2013, doi: 10.1186/1475-2840-12-127.
[13] N. Oyama *et al.*, *Jpn. J. Radiol.*, vol. 29, no. 2, pp. 104–109, 2011, doi: 10.1007/s11604-010-0524-z.
[14] T. Tran, G. Small, M. Cocker, Y. Yam, and B. J. W. Chow, *Eur. Heart J. Cardiovasc. Imaging*,
vol. 15, no. 4, pp. 423–430, 2014, doi: 10.1093/ehjci/jet175.

[15] A. Razanata, P. Prajitno, and D. S. Soejoko, vol. 2, no. 1, pp. 61–66, 2019.

[16] N. Aslanabadi et al., *J. Cardiovasc. Thorac. Res.*, vol. 6, no. 4, pp. 235–239, 2014, doi: 10.15171/jcvtr.2014.018.

[17] A. G. Bertaso, D. Bertol, B. B. Duncan, and M. Foppa, *Arg. Bras. Cardiol.*, pp. 18–28, 2013, doi: 10.5935/abc.20130138.

[18] M. Dagvasumberel et al., *Cardiovasc. Diabetol.*, vol. 11, no. 1, p. 1, 2012, doi: 10.1186/1475-2840-11-106.

[19] J. Mancio et al., *Int. J. Cardiol.*, vol. 249, pp. 419–425, 2017, doi: 10.1016/j.ijcard.2017.09.178.