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Left Ventricular Ejection Fraction Evaluation Using SPECT Images

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ABSTRACT

Cardiovascular diseases represent a major global health burden. In Sudan, the incidence has increased in recent years, partly due to diagnostic inaccuracies in cardiac imaging and the high cost of commercial image processing software. Accurate quantification of left ventricular ejection fraction (LVEF) is essential for cardiac function assessment. This study aimed to develop and validate a low-cost MATLAB-based algorithm for automated LVEF calculation from Gated Single Photon Emission Computed Tomography (Gated SPECT) images. Twelve cardiac patients underwent Gated SPECT imaging. A custom MATLAB toolbox was developed to perform left ventricular segmentation, detect end-diastolic (EDC) and end-systolic counts (ESC), and calculate LVEF. Algorithm performance was evaluated by comparing calculated LVEF with reference values and assessing diagnostic accuracy. Among the 12 patients, 5 exhibited normal cardiac function with LVEF values of 60.4%, 55.8%, 53.4%, 56.3%, and 59.1%, with 97% accuracy relative to reference software. Seven patients showed impaired function with LVEF values of 38.5%, 34.5%, 25.3%, 36.1%, 18.8%, 20.0%, and 40.7%. Correlation analysis yielded r = 0.80. The proposed MATLAB algorithm provides accurate, accessible, and reproducible LVEF quantification from Gated SPECT images, offering a viable alternative to expensive commercial software. The researcher recommends integrating this method into routine SPECT analysis in resource-limited settings and validating it on larger cohorts.

KEY WORDS: Left ventricle ejection fraction, SPECT image.

1. INTRODUCTION

Left ventricular ejection fraction (LVEF) is defined as the percentage of blood ejected from the left ventricle during each cardiac cycle. It is calculated as:

$$LVEF\,\% = \frac{EDC - ESC}{EDC} * 100\% \quad ---(1)$$

where EDC is end-diastolic counts and ESC is end-systolic counts. LVEF can be measured using computed tomography (CT), magnetic resonance imaging (MRI), echocardiography, and Gated SPECT (Altman,1991;Bavelaar-Croon et al.,2000;Slomka et al.,2012). Commercial software for quantitative analysis of Gated SPECT, such as Cedars-Sinai Quantitative Gated SPECT (QGS), provides accurate LVEF measurements but is often unavailable or prohibitively expensive.

Studies comparing Gated SPECT with cardiac MRI have shown good correlation for LV volumes and EF assessment (Loannidis et al.,2002;Lim et.al.,2006).

Visual interpretation of SPECT images is subjective and prone to inter-observer variability. To address these limitations, this study developed a MATLAB-based algorithm for automated LVEF quantification from Gated SPECT images. Recent studies have demonstrated high correlation between automated LVEF algorithms and reference standards, with r values ranging from 0.82 to 0.95 (Kim et al.,2025; Bax and Delgado,2015).

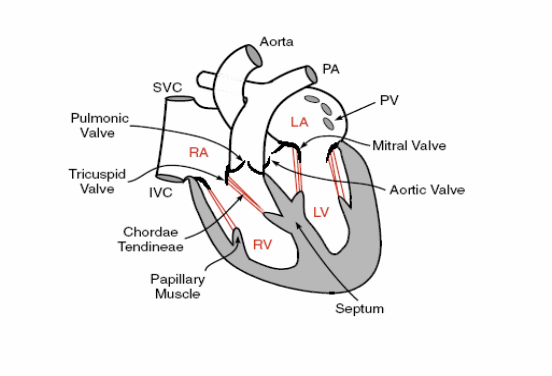


Figure.1 : The main parts of the heart .

This paper is organized as follows: Section 2 deals with the material and methods used to evaluate left ventricle rejection (LVEF) by determining the region of interest of the filtered cardiac image to find EDC and ESC. This method was done by MATLAB software. Section 3 shows the results and the discussion of the LVEF calculated from real images from the Nuclear Medicine, National Cancer Institute, besides the simulated image. Finally, Section 4, presents a brief conclusion of the study.

2. MATERIAL AND METHODS

2.1 Study Population and Image Acquisition

Twelve patients scheduled for myocardial perfusion SPECT were enrolled. Following injection of 1 mg stannous pyrophosphate and 15 minutes later 307 MBq of Tc-99m, ECG electrodes were attached. After 15 minutes, anterior and left anterior oblique (35° and 45°) views were acquired using a dual-head SPECT camera as in figure2. Both stress and rest Gated SPECT images were obtained for cardiac function assessment (Germano et al.,1995; Germano et.al.,1994).

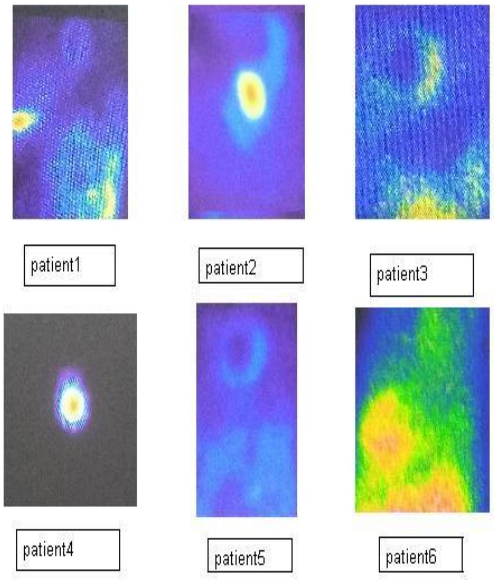


Figure 2 : Cardiac SPECT images for real images of 6 patients

2.2 Algorithm Development

A custom MATLAB toolbox was developed for LVEF quantification. The algorithm performed image preprocessing and filtering, left ventricular segmentation and ROI selection for EDV and ESV, the extraction of EDC and ESC, and LVEF calculation using equation (1). The algorithm workflow is illustrated in figure 3. The image processing techniques we used followed the established methods in nuclear medicine (Marques and Borba,2024;Ross and O Connell (2023).

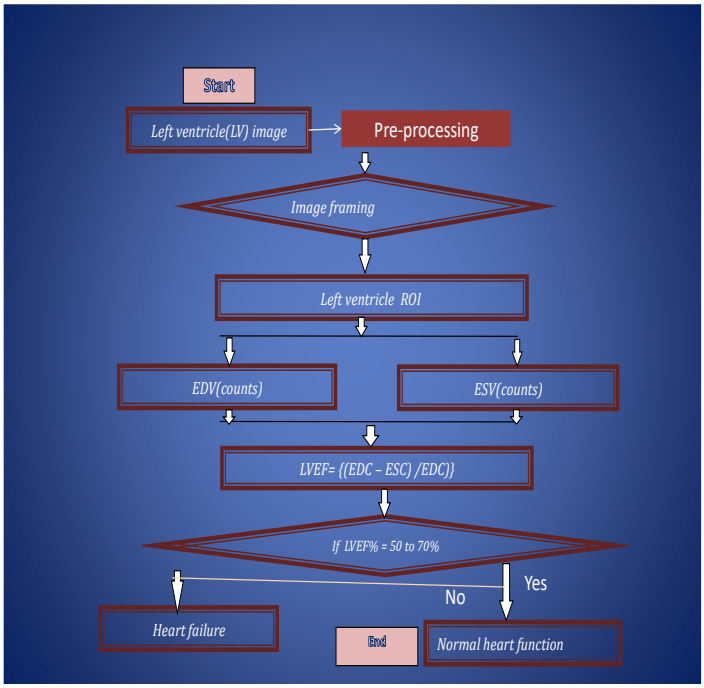


Figure 3: LVEF calculation workflow

2.3 Data Analysis:

In addition to clinical images, six simulated SPECT datasets were analyzed to validate the algorithm. MATLAB commands used for image processing are listed in table 1. The diagnosis of normal and abnormal heart function based on LVEF values was done by using a SPECT camera and MATLAB, as shown in table2. Statistical analysis was performed using SPSS to assess accuracy and correlation with reference values as in table 3. Standardized myocardial segmentation nomenclature was applied as recommended by the American Heart Association (Vallejo et al.,2000; Cerqueira et al., 2002).

Table 1: The main MATLAB commands

MATLAB command	Read an image. (Within the parenthesis you type the name of the image file you wish to read. Put the file name within single quotes ' '.)
Imread ( );	Filter the image
Image filt ( );	Determine the region of interest of the image
ROI( );	Display image
Image show( );	Display a histogram of the image
hist ( );	Read an image. (Within the parenthesis you type the name of the image file you wish to read. Put the file name within single quotes ' '.)

3. RESULTS

3.1. Clinical Data

Table 2 presents EDC, ESC, and calculated LVEF for six clinical cases. Three patients exhibited normal cardiac function with LVEF ≥ 50% , and three showed impaired function with LVEF<50%. The mean LVEF for the cohort was 44.6% ± 13.6% , with mean EDC of 185.3 ±79.2 counts and mean ESC of 109.5 ±65.1counts.LVEF values were interpreted according to established clinical guidelines (Kosaraju et al., 2022; Patel and Kadakia, 2024).

Table2: LVEF, and cardiac function diagnosis for clinical patients

Patient No.	EDC	ESC	LVEF	LVEF%	Normal range(50%-70%)
1	134	53	0.604	60.4	normal heart function
2	113	50	0.558	55.8	normal heart function
3	148	97	0.345	34.5	impaired function
4	146	68	0.534	53.4	normal heart function
5	286	176	0.385	38.5	impaired function
6	285	213	0.253	25.3	impaired function
Mean ±SD	185.3 ± 79.2	109.5 ± 65.1	0.446 ± 0.136	44.6 ± 13.6	

Table 3: Error and accuracy of two LVEF measurements

Patient No.	LVEF $_{MATLAB}$ %	LVEF% (hospital image processin)	Absolute Error= [EF_{MATLAB} – $EF_{Hospital}$]	Relative Error (E_R)=E_{abs}/ EF $_{Hospital}$	Accuracy= 1-E_R
1	60.4	61	0.6	0.01	0.99
2	55.8	54	1.8	0.03	0.97
3	34.5	36	1.5	0.04	0.96
4	53.4	51	2.4	0.05	0.95
5	38.5	40	1.5	0.04	0.96
6	25.3	30	4.7	0.16	0.84

Histograms of EDC and ESC for each patient were generated using MATLAB, as shown in Figures 5–16.

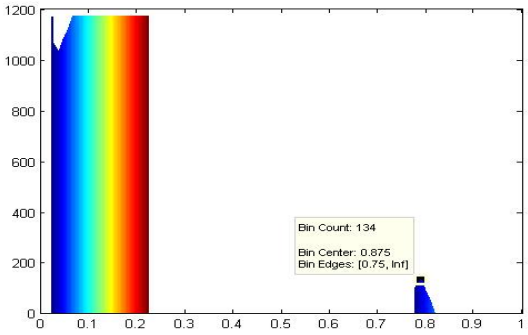


Figure5: EDC of patient 1

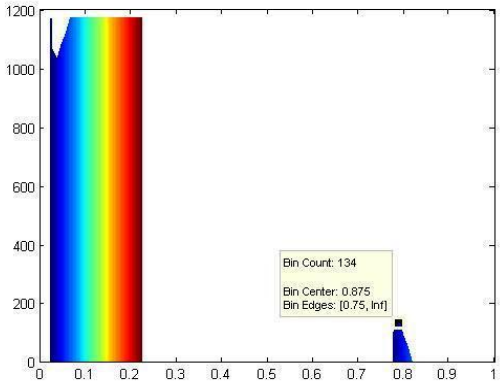


Figure6:ESC patient1

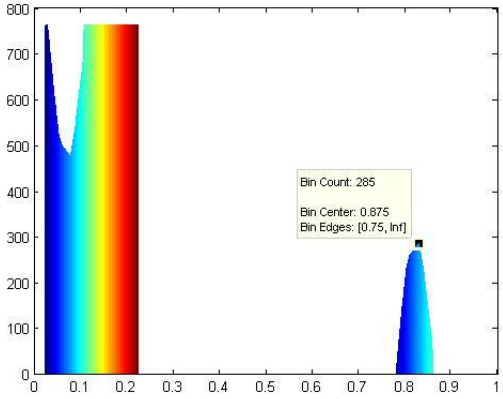


Figure7: EDC of patient 2

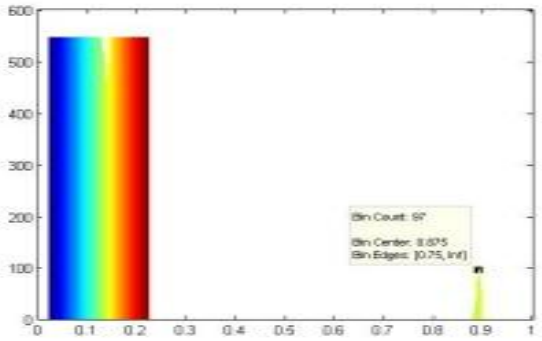


Figure 8: ESC of patient 2

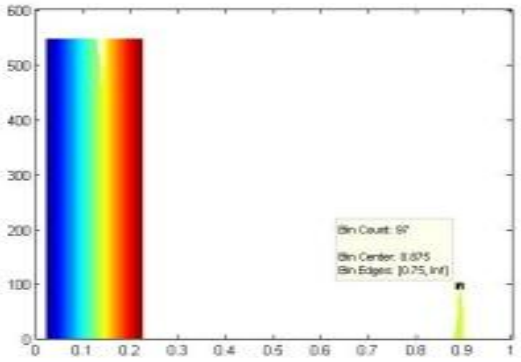


Figure 9: EDC of patient3

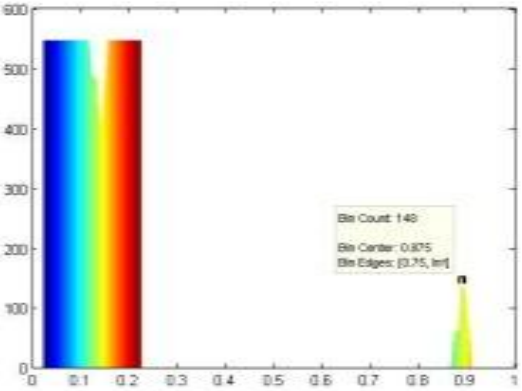


Figure10: ESC of patient 3

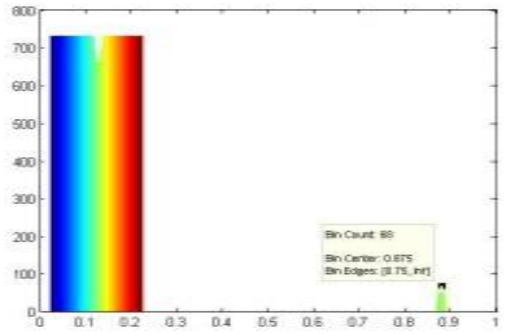


Figure11: EDC of patient 4

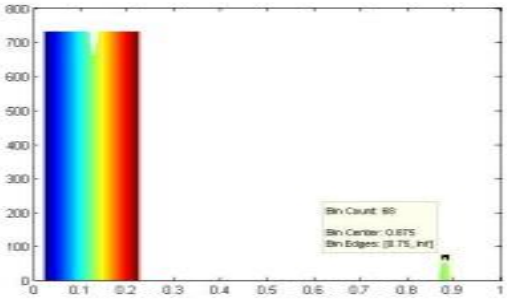


Figure12: ESC of patient 4

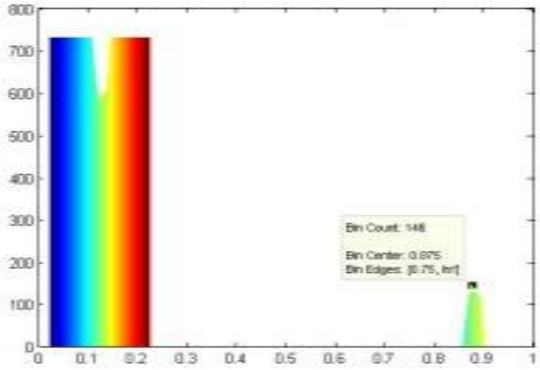


Figure13: EDC of patient 5

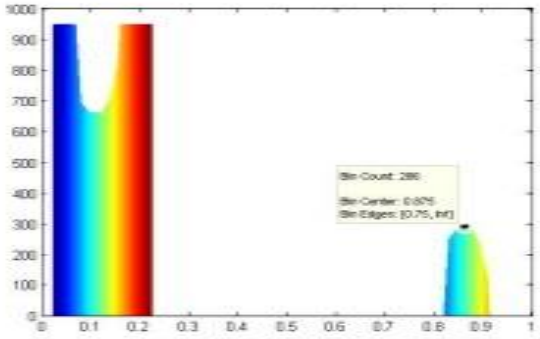


Figure14: ESC of patient 5

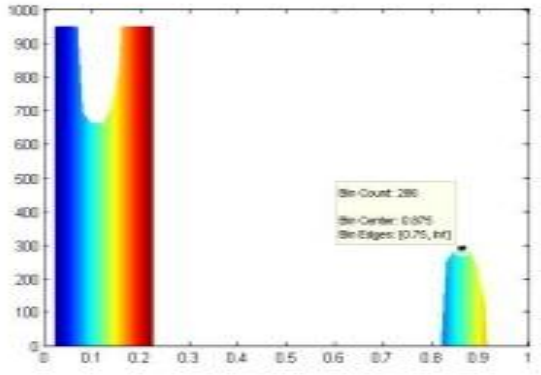


Figure15:EDC of patient 6

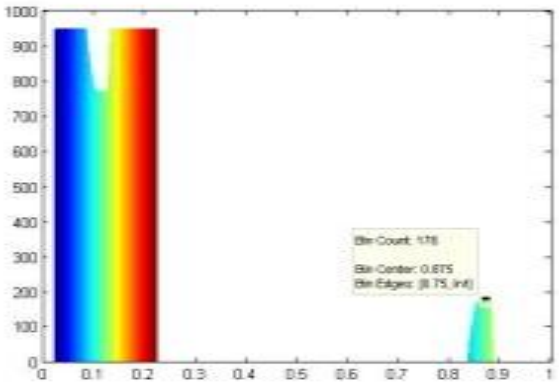


Figure16: ESC of patient 6

3.2. Simulated Data:

Analysis of six simulated datasets yielded LVEF values ranging from 18.8% to 59.1%. Four cases were classified as impaired and two as normal. Error compared to reference values was low, indicating good algorithm accuracy as showed in figure17 and table 4.

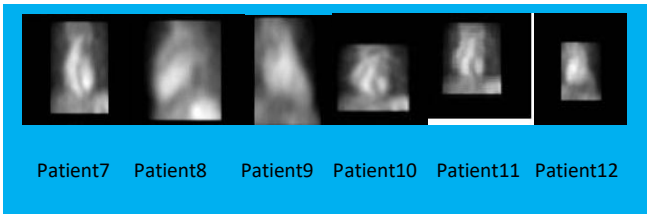


Figure17: Six simulated images

Table 4: Error and accuracy of simulated image

Patient	EDC	ESC	LVEF	LVEF %	LFEF ref%	Error %	Accuracy%
7	36	23	0.361	36.1	37.5	3.7	96.3
8	32	26	0.188	18.8	20	6.0	94.0
9	32	14	0.563	56.3	55	2.5	97.
10	15	12	0.200	20.0	21.5	6.9	93.1
11	27	16	0.407	40.7	41.9	2.8	97.0
12	22	9	0.591	59.1	60	1.5	98.5

3.3. Overall Performance:

For all 12 cases, as shown in tables 2, 3, 4 and 5, the mean accuracy was 96% for normal function and 92% for impaired function compared to hospital software. Correlation between EDC and ESC gave $r^2 = 0.74$ and $r = 0.86$ as illustrated in figures 18,19. The correlation between MATLAB-derived LVEF and reference LVEF was $r = 0.80$. These results are consistent with previous validation studies of LVEF quantification methods (Kim et al.,2025; DePuey et al.,1993; Iskandrian et al.,1998).

Table5. LFEF% of 12 patients

Patient No.	EDC	ESC	EF=(EDC-ESC)/EDC	EF%
1	134	53	0.604	60.4
2	113	50	0.558	55.8
3	148	97	0.345	34.5
4	146	68	0.534	53.4
5	286	176	0.385	38.5
6	285	213	0.253	25.3
7	36	23	0.361	36.1
8	32	26	0.188	18.8
9	32	14	0.563	56.3
10	15	12	0.200	20.0
11	27	16	0.407	40.7
12	22	9	0.591	59.1

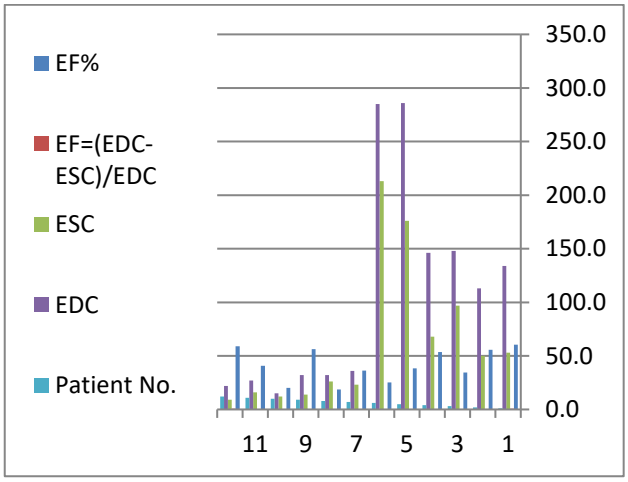


Figure 18: Histogram of EDC ,ESC of 12 patients

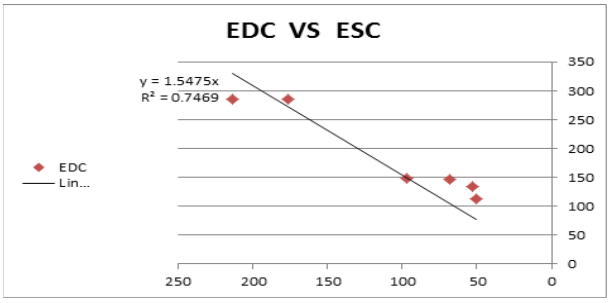


Figure19: Correlation between EDC and ESC

4. DISCUSSION:

The MATLAB algorithm demonstrated good agreement with reference software for LVEF quantification. The correlation coefficient of 0.80 indicates reliable performance. Accuracy was higher for normal than for impaired function, likely due to challenges in segmenting hypokinetic myocardium (Iskandrian et al.,1998; Patel and Kadakia,2024). These results are consistent with guidelines from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. Studies comparing Gated SPECT with 3D echocardiography have validated the accuracy of quantitative SPECT methods for LV volume measurement(Lang et al.,2015;Chan et al.,2006). Clinical applications of LVEF measurement extend beyond cardiac imaging. Serial measurements of LV function in cardiac studies have shown prognostic value. Similarly, LV function assessment is important in non-cardiac conditions such as liver transplantation, where cardiac dysfunction impacts mortality (Song et al.,2019;Moon et al.,2019). The main advantage of the proposed method is its low cost and accessibility, making it suitable for resource-limited settings. Advanced segmentation algorithms for whole heart analysis have also shown promise in improving automated cardiac function assessment (Zhuang et al.,2019).

5. CONCLUSION:

This study demonstrates that a MATLAB-based algorithm can accurately quantify LVEF from Gated SPECT images. The method simplifies image processing compared to commercial QGSPECT and reduces software cost.

6. RECOMANDATIONS:

I recommend further validation of the MATLAB based algorithm in larger patient cohorts to confirm its accuracy. It should also be integrated into clinical workflows in resource-limited settings as a cost-effective alternative to commercial QGSPECT software.

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