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Assessing the Accuracy of Region of Interest Drawing by Radiological Technology Students for Determining Left Ventricular Function Values in Nuclear Medicine

Kanokon Poonak,[1] Peerawan Chochai,[2] Jatupat Rammapap,[1] and Sorawit Injarun[1]

[1] *Department of Radiological Technology, Faculty of Medicine Vajira Hospital, Navamindradhiraj University, Bangkok 10300, Thailand*

[2] *Department of Radiology, Faculty of Medicine Vajira Hospital, Navamindradhiraj University, Bangkok 10300, Thailand*

ABSTRACT Multiple-gated acquisition (MUGA) scans have been utilized to assess left ventricular ejection fraction (LVEF) values. Variations in region of interest (ROI) delineation by different technologists can impact LVEF results. This study investigated the intra-reliability and inter-reliability of ROI delineation. The percentage of LVEF was calculated from the patient's left ventricular function imaging using a semi-automated method. Means, standard deviations, intraclass correlation coefficients (ICC), and Bland-Altman plots were generated using SPSS software. Intraclass correlation for intra-rater reliability ($ICC_{(3,1)}$) ranged from 0.94 to 0.95, and that for inter-rater reliability ($ICC_{(2,1)}$) was 0.88 to 0.89. The Bland-Altman plots revealed mean differences in three ROI drawings: 0.84, 1.49, and 1.66. The calculated mean LVEF values obtained by radiological technology students were correlated with the standard values based on the ROI drawings, with correlation coefficients of 0.92 and 0.87. This study demonstrated that adequately trained radiological technology students could reliably draw ROIs for LVEF calculation in patients undergoing MUGA scan. The acceptable inter-rater reliability between the two students and the LVEF values were similar to those of experts supported this conclusion. The findings suggested that well-trained new technologists or radiological technology students can effectively contribute to MUGA analysis, potentially alleviating workload pressures on expert technologists.

Keywords: Left ventricular ejection fraction, Accuracy of ROI drawing, Radiological technology student

Corresponding author E-mail: kanokon@nmu.ac.th

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Introduction

Many chemotherapy and targeted therapies that are effective in treating cancers have increased the number of cancer survivors today despite some complications, especially cardiovascular disease. The most common condition is cardiotoxicity from chemotherapy, (cardiovascular toxicity) which decreases the efficiency of the heart.[1,2] The assessments of cardiac function using the left ventricular ejection fraction (LVEF) measurement before, after, and during chemotherapy are therefore important. Convenient ways to measure LVEF and also non – invasive assessment modalities include echocardiogram (Echo) and multiple – gated acquisition (MUGA) scan.[3]

The LVEF value is calculated based on the MUGA scan information, using the equation:[4,5]

$$\%\text{LVEF} = \frac{(\text{Background corrected end – diastolic count} - \text{Background corrected end – systolic counts})}{\text{Background corrected ED counts}} \times 100$$

Generally, the LVEF value above 55% is typically considered normal, while a significant decrease (greater than 10%) may indicate early signs of cardiotoxicity.[4]

The process entails an operator precisely defining the area of interest in the medical image by creating regions of interest (ROIs).[4] This procedural step significantly influences the calculation of the LVEF value.[5] A thorough understanding of the ROI determination process is critical, as it can result in either overestimating or underestimating the LVEF value. Proficiency in ROI drawing and background positioning also affects the LVEF value no matter which organs. It has been found that the work experience of each operator has a different effect on the ROI drawing.[6-8] Incorrect LVEF will affect the planning of chemotherapy treatment. Therefore, the accuracy of ROI drawing each time is important for calculating the LVEF value. This study, consequently, compared the ROIs drawn by the same researcher and radiological technology students, and those drawn by the students with the LVEF value obtained from a teacher with over 15 years of experience as a compared value to determine their significant differences.

Materials and Methods

Data Acquisition

This study utilized MUGA raw data acquired from January 2012 to December 2022 at the Faculty of Medicine Vajira Hospital. The data were collected using a single photon emission computed tomography/computed tomography (SPECT/CT) scanner, the INFINIA HAWKEYE 4 GP3 model from GE Medical Systems Israel Ltd.

Data Analysis

The patient data were analyzed by creating ROIs using the semi – automated feature of the Xeleris® functional imaging workstation, which includes software for LVEF calculation. Three ROIs were drawn on the left ventricle (LV) region including ROI of end – diastolic volume (EDV), ROI of end – systolic volume (ESV) and ROI of background (BKG). Inclusion criteria stipulated the presence of

clear LV visualization from the MUGA scan after ROI delineation by students. The exclusion criterion was images of patients undergoing a MUGA scan with rejected heartbeats exceeding 20. The intra – rater reliability sample size was 215, and the inter – rater reliability sample size was 332.

Statistical Analysis:

This study aimed to evaluate the reliability of image analysis for MUGA scan derived the LVEF by comparing results from two inexperienced fourth – year radiological technology students who received training in nuclear medicine image analysis (MUGA scans) with those of a radiological technologist with over 15 years of experience. The experienced technologist's LVEF determinations were considered as the established reference values for this study. The evaluation employed three distinct measures of reliability:

1. Intra – rater reliability: This assessment compared LVEF values obtained by each student when they re – drew ROIs on the same MUGA scan image. This approach evaluated repeatability of analysis using the same image.

2. Inter – rater reliability between students: This measure compared LVEF values derived from ROIs drawn by the two students on the same MUGA scan image. This assessed agreement between the students' analyses.

3. Inter – rater reliability between student and expert: This distinct measure compared LVEF values obtained from ROIs drawn by each student with the LVEF values derived by the experienced technologist for the same image. This evaluated agreement between the students' analyses and the standard provided by the experienced professional.

To assess intra – rater reliability, each student independently redrew ROIs in the same image three times with at least a three – day interval between each redraw. The mean LVEF value, standard deviation, and intraclass correlation coefficient (ICC) were calculated for all three drawings. Additionally, a Bland–Altman plot was generated to visualize the agreement between the repeated measurements. $ICC_{(2,1)}$ was used to measure agreement between student ratings for inter – rater reliability (student – to – student). Intra – rater reliability, reflecting the consistency of measurements by individual students, was assessed using $ICC_{(3,1)}$.

To evaluate inter – rater reliability, each student independently redrew three ROIs in the same patient image. The mean LVEF values obtained by the two students were compared, and a Bland – Altman plot was constructed to assess the agreement between their measurements.

Statistical analysis was conducted using the chi – square test to compare data obtained from the two students with the reference value. Correlation was used to examine the direction of the relationship between the variables, with the correlation coefficient (r) indicating the strength of the relationship between the values obtained from the two students and the reference values.

All of the statistical analysis was performed using SPSS Version 28.0 (IBM SPSS Statistics; IBM Corporation, Armonk, NY, USA).

Ethical approval

This research was approved by the Institutional Review Board of the Faculty of Medicine Vajira Hospital on February 12, 2022 (COA 050/2565).

Results

Intra - rater Reliability:

Intra - rater reliability was assessed by comparing the LVEF values obtained from the redrawing ROIs using Xeleris® Functional Imaging Workstation, an ejection fraction analysis software. This analysis was performed on a sample of 215 MUGA scans from 215 samples. For each student (Student 1 and Student 2), the mean and standard deviation (SD) of LVEF values were calculated based on their three independent ROI drawings on the same image. As shown in Table 1, the $ICC_{(3,1)}$ indicated excellent internal reliability, ranging from 0.94 to 0.95 (Table 1).

Table 1 Intra - rater reliability between radiological technology students comparing the LVEF values, $ICC_{(3,1)}$ and *p*-values

Student	LVEF (Mean±SD)	$ICC_{(3,1)}$ (reliability at 95%)	*p*-value
1	60.43±8.16	0.94 (0.93-0.96)	< 0.001
2	59.0±8.24	0.95 (0.93-0.96)	< 0.001

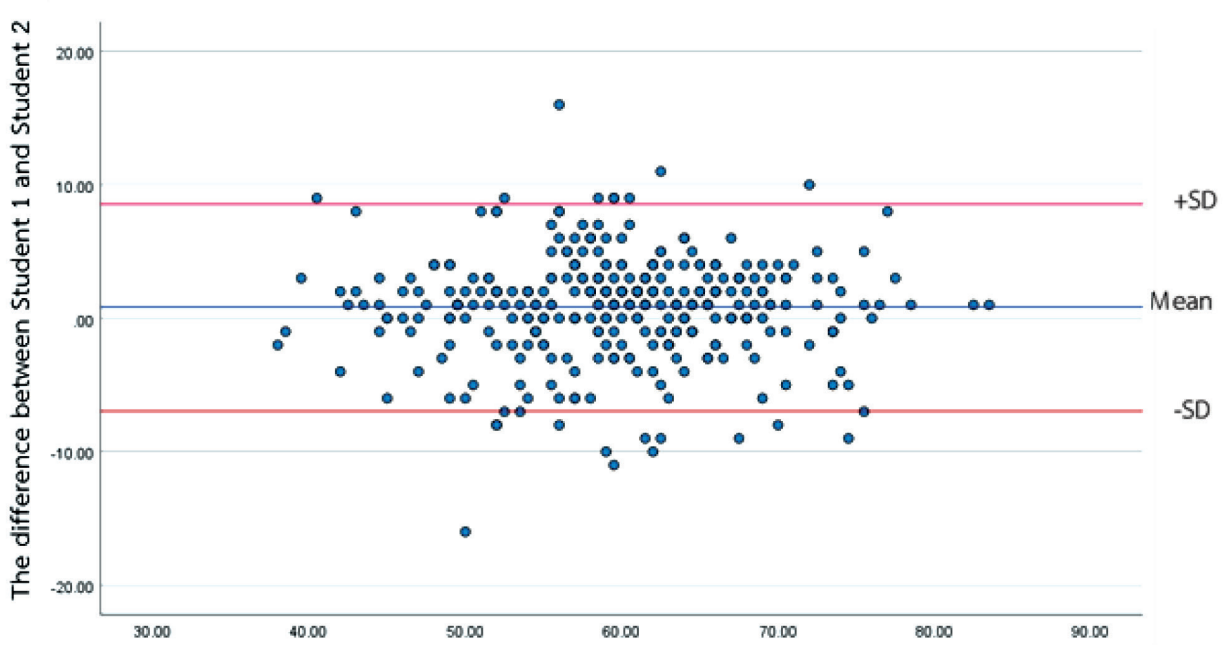
Inter - rater Reliability between students:

Inte - rater reliability was assessed by comparing the LVEF values obtained from the ROIs drawn by Students 1 and 2 on a sample of 322 MUGA scans. The mean and standard deviation of LVEF values were then calculated for each student. As shown in Table 2, the $ICC_{(2,1)}$ indicated good agreement between the students, ranging from 0.88 to 0.89 (Table 2).

Table 2 Inter - rater reliability between radiological technology students comparing the LVEF values, $ICC_{(2,1)}$ and *p*-values

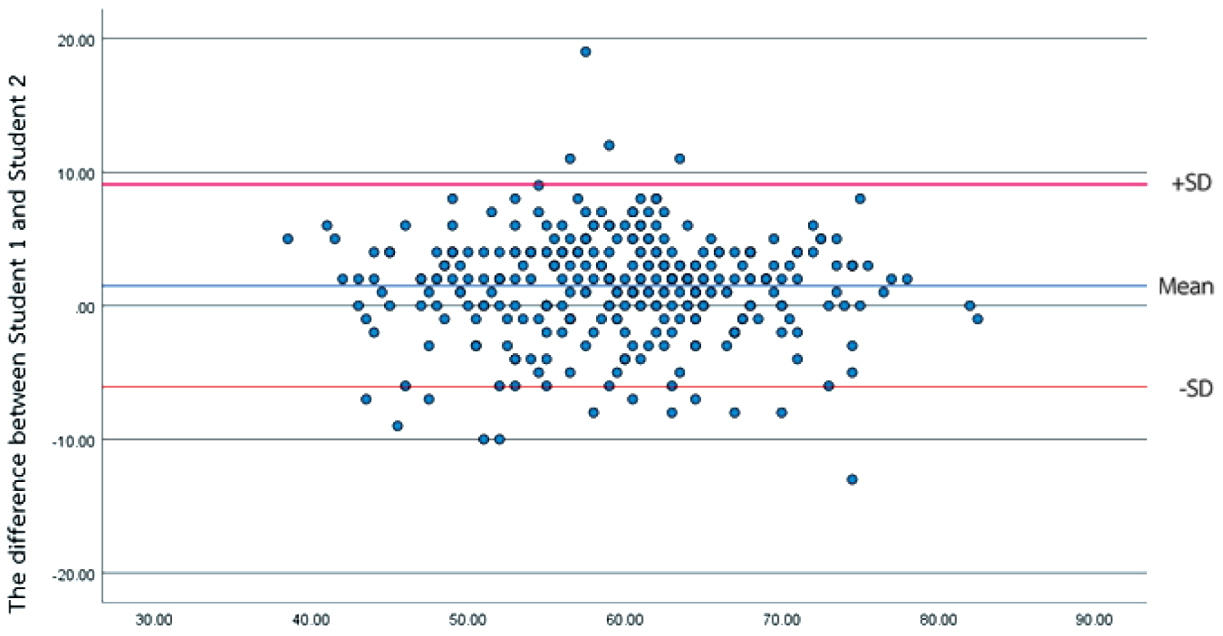
Student	LVEF (Mean±SD)	$ICC_{(2,1)}$ (reliability at 95%)	*p*-value
Drawing 1			
Student 1	60.17±8.37	0.88 (0.86-0.90)	< 0.001
Student 2	59.35±8.36		
Drawing 2			
Student 1	60.48±8.20	0.89 (0.86-0.91)	< 0.001
Student 2	58.99±8.28		
Drawing 3			
Student 1	60.62±8.28	0.89 (0.87-0.91)	< 0.001
Student 2	58.97±8.51		

Bland - Altman plots were further employed to visualize the agreement between repeated LVEF values obtained by Students 1 and 2 across the three sessions. These plots revealed mean differences in LVEF values of 0.84, 1.49, and 1.66 for the first, second, and third sessions, respectively. The limits of agreement, defined by the 95% confidence interval, ranged from - 6.96 to 8.63, - 6.09 to 9.07, and - 6.01 to 9.33 for the corresponding sessions (Figures 1 - 3).



The mean %LVEF of Student 1 and Student 2 in the 1st drawing

Figure 1 Bland Altman plot showed the differences in the mean LVEF values obtained by Students 1 and 2 from the first drawing



The mean %LVEF of Student 1 and Student 2 in the 2nd drawing

Figure 2 Bland Altman plot showed the differences in the mean LVEF values obtained by Students 1 and 2 from the second drawing

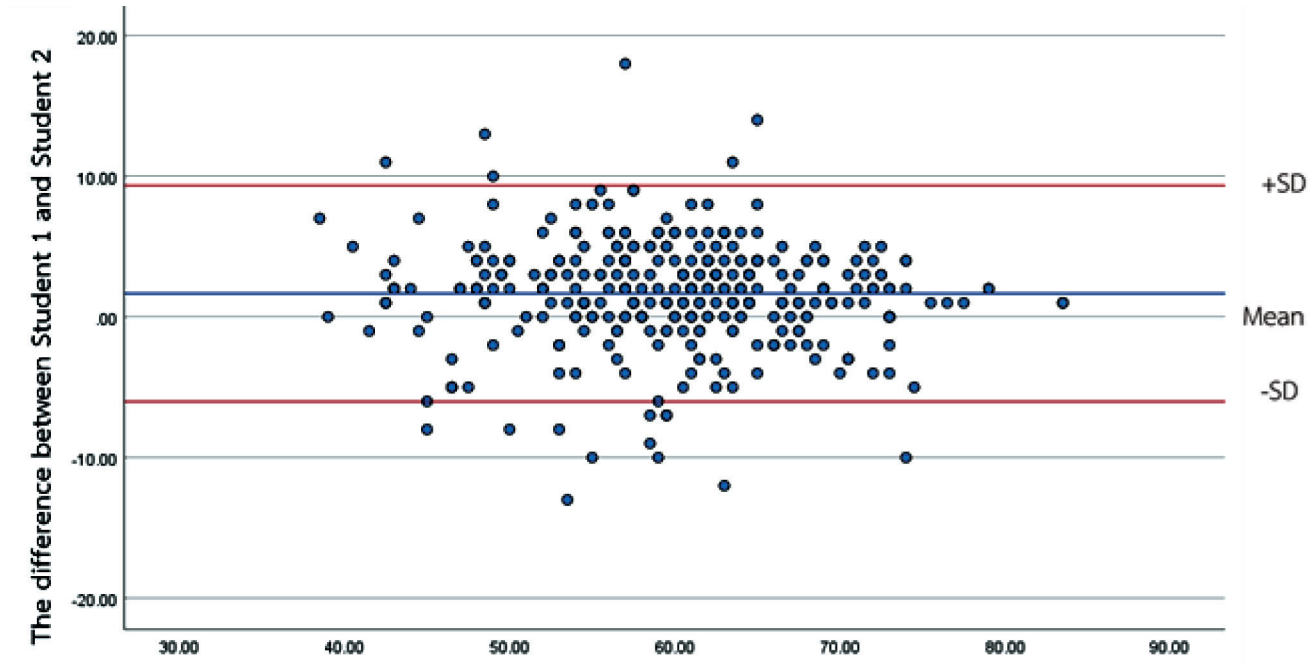


Figure 3 Bland Altman plot showed the differences in the mean LVEF values obtained by Students 1 and 2 from the third drawing

Agreement with Reference Values:

The students' measurements were compared to the reference LVEF value to assess agreement. The LVEF values obtained by Students 1 and 2 were compared with the reference value using a chi-square test to determine any significant differences in means (Table 3). Additionally, the correlation coefficient (r) was calculated to assess the direction and strength of the relationship between the students' LVEF values and the reference value (Table 4).

Table 3 Comparison of the LVEF means, standard deviations, and *p*-values obtained by Students 1, 2, and the reference value

Source	LVEF (Mean±SD)	*p*-value
Reference value	61.172±7.78	
Student 1	60.43±8.16	< 0.001
Student 2	59.09±8.24	< 0.001

Table 4 The correlation between students' LVEF values and the reference value

Student	Correlation coefficient (r)	*p*-value
Student 1	0.92	0.001
Student 2	0.87	

Discussion

This study investigated the impact of ROI drawing accuracy on LVEF calculations in MUGA scans performed on patients. The findings demonstrated excellent intra – rater reliability ($ICC_{(3,1)}$ range: 0.94 – 0.95, $p < 0.001$) and good inter – rater reliability ($ICC_{(2,1)}$ range: 0.88–0.89, $p < 0.001$) among students performing the analysis. These results suggested that with proper training, students could achieve consistent ROI delineation.

Based on the student's ROI drawing repeatability (n = 3), the means and standard deviations (SD) of the LVEF values for the first and second students, and the reference values were 60.43±8.16, 59.09±8.24, and 61.17±7.78 respectively. The three values were found to be significantly different ($p < 0.001$). Using the Bland Altman plot graph to test the agreement between students (inter – rater reliability) by comparing the LVEF values obtained from drawn ROIs, the value was 95% of the limit of agreement. The LVEF mean differences between the two students' ROI drawings repeatability (n = 3) were 0.84, 1.49, and 1.66, respectively.

Tomaru Y, et al.[6] found that the experience of nuclear medicine technologists might cause differences in renal ROI drawing, particularly manual ROI drawing ($p < 0.0001$). In addition, the correlation analysis and Bland – Altman analysis revealed that the two variables were correlated. Similarly, Sachpekidis C, et al.[8] indicated that experience played a very important role in analyses or calculations. Therefore, there was be a training period for operator's practice to become proficient, especially in using an automated tool for processing alone. As inaccuracies may occur, it may also be used in conjunction with manual methods.

From the study, it was found that new students must gain experience in drawing ROIs to achieve accuracy of ROI drawing. This reliability impacted on LVEF calculations for patients undergoing a MUGA scan. There was consistency in reliability scores between each student and the expert using as a reference value. The findings supported both the interpreting physician′s confidence in reading the results and the referring physician's confidence in using the LVEF value for treatment planning.

In this study, LVEF was determined using a single image processing program. It had never been performed in the patients examined by different image processing programs. However, Amnuaywattakorn S, et al.[9] also performed a study to determine LVEF from a MUGA scan by imaging with the same SPECT machine and the results were analyzed with different image processing programs. It was found that LVEF obtained was of a high agreement value. Therefore, the patient's data undergoing LVEF which shown different image processing programs did not affect the accuracy of LVEF values or the physician's treatment decisions.[9]

Despite using the semi – quantitative method, it was difficult to control the size and site of background ROIs, causing a different LVEF value in each analysis.[4] Moreover, it was found that the work experience of each operator had a different effect on the ROI drawing, resulting in different analytic values in many studies.[5–7]

Conclusion

The research findings revealed that individuals with comprehensive training could accurately draw ROIs for LVEF calculation in

patients undergoing a MUGA scan. Both intra - and inter - rater reliabilities demonstrated consistency in measuring LVEF values compared with those undertaken by experienced experts. This suggested that novice operators, gaining adequately trained, may get proficiently draw ROIs, providing reliable results.

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การประเมินความเที่ยงในการวาดบริเวณที่สนใจของนักศึกษารังสีเทคนิค เพื่อคำนวณค่าการทำงานของหัวใจห้องล่างซ้ายในงานทางเวชศาสตร์นิวเคลียร์

กนกอร ภู่นาค[1] พีระวรรณ โชชัย[2] จาฏุพัจน์ รัมมะภาพ[1] และ สรวิชญ์ อินจรัญ[1]

[1] ภาควิชารังสีเทคนิค คณะแพทยศาสตร์วชิรพยาบาล มหาวิทยาลัยนวมินทราธิราช กรุงเทพมหานคร 10300

[2] ภาควิชารังสีวิทยา คณะแพทยศาสตร์วชิรพยาบาล มหาวิทยาลัยนวมินทราธิราช กรุงเทพมหานคร 10300

บทคัดย่อ การตรวจสมรรถภาพของหัวใจด้วยวิธี multiple-gated acquisition scan (MUGA) ใช้ในการประเมินการทำงานของหัวใจห้องล่างซ้าย (left ventricular ejection fraction; LVEF) โดยการวาดบริเวณที่สนใจ (region of interest; ROI) ที่แตกต่างกันมีผลต่อค่า LVEF งานวิจัยนี้จึงทำการศึกษาความเที่ยงภายในผู้ประเมินและระหว่างผู้ประเมินจากการวาด ROIs โดยคำนวณหาค่า %LVEF จากภาพการตรวจผู้ป่วยด้วยวิธีการวาด ROIs แบบ semi-automated จากนั้นนำค่า %LVEF ที่ได้มาวิเคราะห์หาค่าเฉลี่ยรวมและส่วนเบี่ยงเบนมาตรฐาน หาค่าความเชื่อมั่น (ICC) และสร้างกราฟ Bland-Altman plot ด้วยโปรแกรม SPSS โดยผลการศึกษาพบว่าค่าความน่าเชื่อถือภายในตัวผู้ประเมิน ($ICC_{(3,1)}$) อยู่ระหว่าง 0.94 ถึง 0.95 และระหว่างผู้ประเมิน ($ICC_{(2,1)}$) อยู่ระหว่าง 0.88 ถึง 0.89 จากกราฟ Bland Altman plot แสดงค่าเฉลี่ยความแตกต่างระหว่างผู้ประเมินที่ 1 และผู้ประเมินที่ 2 ในการวาด ROIs ทั้ง 3 ครั้ง เท่ากับ 0.84, 1.49 และ 1.66 ตามลำดับ ค่าเฉลี่ย %LVEF ที่ได้จากการคำนวณระหว่างผู้ประเมินที่เป็นนักศึกษารังสีเทคนิคสองคนและเปรียบเทียบกับค่ามาตรฐานจากการวาด ROIs มีความสัมพันธ์กันมากในเชิงบวกเท่ากับ 0.92 และ 0.87 จากการศึกษาพบว่าหากนักศึกษารังสีเทคนิคได้รับการฝึกฝนทำให้มีความชำนาญเพียงพอในการวาด ROIs เพื่อคำนวณ %LVEF ในการตรวจ MUGA scan พบว่าความเที่ยงภายในตัวผู้ประเมินมีความน่าเชื่อถืออยู่ในระดับดีมากและความเที่ยงระหว่างตัวผู้ประเมินมีค่าการยอมรับอยู่ในเกณฑ์ดี และค่า %LVEF ที่ได้มีความใกล้เคียงกับผู้ชำนาญการ ดังนั้นหากนักรังสีเทคนิคปฏิบัติงานใหม่หรือนักศึกษารังสีเทคนิคที่ได้รับการฝึกฝนอย่างดีจะสามารถปฏิบัติงานในการวิเคราะห์การตรวจ MUGA ได้อย่างมีประสิทธิภาพ ซึ่งช่วยลดภาระงานของนักรังสีเทคนิคได้

คำสำคัญ: การทำงานของหัวใจห้องล่างซ้าย, ความเที่ยงในการวาดบริเวณที่สนใจ, นักศึกษารังสีเทคนิค