Comparison of totally automated and manual processing for calculation of left ventricular volumes and ejection fraction using gated myocardial perfusion SPECT

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Abstract
Gated single-photon emission computed tomography (SPECT) allows for the assessment of myocardial left ventricular ejection fraction and left ventricular volumes. There is conflicting data regarding the difference between automated and manual processing of gated myocardial SPECT images. The purpose of this retrospective “cross-sectional study is to compare the degree of variability between automated and manual processing of Quantitative Gated SPECT algorithms for assessing left ventricular volumes and ejection percent”. Study was carried out in the Nuclear Medicine department at the Security Forces Hospital, Riyadh, Saudi Arabia, and comprised of 96 participants who “underwent” both stress and “rest gated” myocardial perfusion “imaging” (MPI) from February to May 2021. Data were analyzed “using SPSS for Windows (version 22; IBM Corp., Armonk, NY, USA).

The mean of EF, ESV, and EDV on stress test using the automatic technique were 62.46 ± 14.62%, 45.00 ± 37.10 ml, and 107.01 ± 43.70 ml, respectively while using the manual technique were 57.21±14.80%, 44.35±35.93 ml, and 93.26±39.14 ml, respectively. The mean of EF, ESV, and EDV on rest test using the automatic technique were 62.85± 15.47%, 43.44± 36.35 ml, and 104.27±42.51 ml, respectively while using the manual technique were 57.74±15.33%, 43.30±36.42 ml, and 91.72±41.50 ml, respectively. For LVEF and EDV, the difference between automated and manual techniques is statistically significant (p<0.05). However, no “statistically significant difference” exists between automated and manual ESV techniques (p>0.05).

Discrepancies were observed that exist by using the fully automated and manual technique for determining LVEF and Left ventricular volumes by gated MPI.

Introduction
The most often utilized basic metrics to estimate global LV function for therapy, clinical follow-up, and epidemiology are left ventricular (LV) volume and ejection fraction (EF). End diastolic and end-systolic volumes (EDV/ESV) and left ventricular (LV) ejection fraction (EF) are regarded as critical parameters in the clinical management of heart disease. Determining suitable threshold levels is critical for defining clinical relevance.

A variety of variables influence the accuracy of ventricular volume and EF estimation. Any considerable change in LVEF from baseline (a drop of 10%) is an early signal of heart failure and may precede any symptoms of cardiac illness. Technological advancements resulted in the emergence of automatic and semi-automatic processing modes and the growth of diverse processing software. However, these advancements raised the possibility of variance in estimating the LVEF. Once the gated image is acquired, algorithms and software are used to determine the LVEF from the left ventricle at end-systole and end-diastole regions of interest. In patients with coronary artery disease and decreased left ventricular function, LVEF and LV volume values predict survival. Identifying people at risk of having a cardiac event is thus the cornerstone of non-invasive examination of patients with reduced LV function. Gender substantially affects normal LVEF readings, whereas age and body weight have a lower effect. Left ventricular ejection fraction and LV chamber sizes should be assessed qualitatively and objectively. Since serial monitoring of LVEF fluctuations can alter patient treatment and administration, the computation of

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Gated SPECT, Processing method, Left ventricular ejection fraction, Left ventricular volumes, Myocardial perfusion

Imprint
LVEF must be accurate, reproducible, and repeatable. The SPECT is considered as the best detection for cardiac failure. Other modalities to detect cardiac disease are cardiac MRI or a planar multi-gated cardiac blood pool acquisition (MUGA). However, the CMR has the same significance as SPECT scan.

Several authors have published algorithms and validation studies for automated and semi-automated chamber segmentation, regional mapping, and quantification of global myocardial function from SPECT datasets. The quantification of SPECT is dependent on myocardial radioactivity count densities, which may be altered by attenuation. Visualization of ventricular perfusion in any plane has been made possible by SPECT. SPECT has enabled the mapping of the function of the overall left ventricular myocardium into single images to produce ungated three-dimensional and gated four-dimensional images and calculate the volumes of the chambers.

Most software systems calculated LVEF by gated SPECT and reported in women as much higher than in males, maybe because women's hearts are smaller than models used and there are more inaccuracies or physiological differences. Normal, slightly, moderately, or severely increased volume can be classified.

Furthermore, leading to further recent developments, automated quantitation remains an important field of research. New software, for example, that evaluates automated LV contours for possible errors has been demonstrated to minimize the degree of human monitoring. Recent generations of nuclear medicine computer systems have significantly lowered the overall processing interval of gated SPECT scans with quicker processing speeds. Algorithms can automatically execute gated SPECT data filtering, restoration, and reorientation, decreasing or excluding the requirements for operator intervention. This automation enables the batch processing of many gated experiments, reducing the time necessary to generate final images and enhancing the consistency of results. Software programs that automatically calculate endocardial and epicardial surfaces from data in each gating interval display these surfaces in cinematic mode as contours overlaid on images in two or three dimensions and derive global ejection fraction values from end-systolic and end-diastolic intervals save time (and increase accuracy).

Another exciting advancement has been the application of machine learning to integrate automated imaging parameters with clinical data for improved clinical diagnosis and individualized prediction of prognostic results. On the other hand, one research approved that the development increased the variation in determining the cardiac volume and LVEF. However, other research proves that there are no significant differences between automated and manual processing, but on the contrary, it saves time for workers. In addition, rapid detection of variations allows for increased surveillance to prevent subsequent problems, implement preventative measures, or identify changes in therapies or patient care.

This study aimed to investigate the substantial differences in cardiac volume (end-systolic and end-diastolic volume) and EF depending on whether the processing was automated or manual.

Materials and Methods

Study Population

A retrospective cross-sectional study was carried out in the Nuclear Medicine department at the Security Forces hospital located in Riyadh, Saudi Arabia. The total number of patients included in the study was 96 who underwent both stress and rest gated myocardial perfusion imaging (MPI) as per the 2-day protocol from February till May 2021. Imaging was performed on Siemens E-cam and Symbia SPECT systems. Ejection fraction (EF), end-diastolic volume (EDV), and end-systolic volume (ESV) were first processed totally automatically, followed by manually modifying above mentioned parameters using Cedars-Sinai QGS software.

Ethical consideration

The research was carried out in accordance with the principles described in the Helsinki Declaration. All processes were carried out in accordance with the applicable norms and legislation.

Statistical Analysis

Data were analyzed using SPSS for Windows (version 22; IBM Corp., Armonk, NY, USA). The values are given as mean SD. P-values of 0.05 are regarded as statistically significant. The coefficient of variance (CV) was determined by dividing the standard deviation of the difference between data by their mean. The t-test was used to investigate differences in mean difference.
Results

Ninety-six patients were scanned in the period from February to May 2021. Demographics and clinical data are demonstrated in ‘Table 1’. The mean age is 61.1 and the range is from 51 to 71. The cardiac disease is more in males is 64.6% and the female about 35.4%. Because the majority of the patients have risk factors for heart disease such as “diabetes mellitus, hypertension, dyslipidemia”, smoking, and a family medical history of cardiac disease, we conducted an analysis to retrieve the risk factors that impact the study’s results and observed that hypertension is the most common risk factor for cardiac disease (77.1 percent).

The mean of EF, ESV, EDV on stress test using the automatic technique were 62.46 ± 14.62%, 45.00 ± 37.10ml, and 107.01 ± 43.70 ml, respectively. The mean of EF, ESV, EDV on stress test using the manual technique were 57.21±14.80%, 44.35 ±35.93ml, and 93.26±39.14 ml, respectively.

We classified the patients according to documented findings on stress test into normal and abnormal. Comparison between automatic and manual techniques for patients with documented normal findings are demonstrated in detail in ‘Table 2’, respectively.

Comparison between automatic and manual techniques for patients with documented abnormal findings on stress and rest tests are demonstrated in ‘Table 3’ and ‘Table 4’, respectively.

There is a “statistically significant difference” between automatic and manual techniques for EF and EDV “(p<0.05) as shown in (Fig. 1) and (Fig. 2). However, there is “no statistically significant difference” between automatic and manual techniques for

** Abbreviations EDV: End-diastolic volume; ESV: End-systolic volume; EF: Ejection fraction**
ESV (p>0.05) as shown in (Fig. 3). We compare between automated and manual processing for EF, EDV, and ESV in stress test as shown in (Fig. 4) and rest as shown in (Fig. 5).

Discussion

Accurate and valid end-diastolic and end-systolic frame detection procedures would enable the development of entirely automated procedures for objective assessment of the LV function, such as automated computation of EF and stroke volume, strain imaging, and wall thickening. However, gated myocardial perfusion single-photon emission computed tomography (SPECT) has been widely used to measure perfusion and LV functional parameters in patients with suspected heart disease. It has proven a high correlation with the results of other modalities.

Automated analysis and quantification display techniques for assessing perfusion and function from myocardial perfusion SPECT have been devised and proved to work in the great majority of patients. Automated software algorithms use different feature extraction procedures when applied to radiologic images. Whenever necessary, software programmers aim to integrate sanity tests, which question if a particular contour, for example, makes rational sense of general human anatomy. Simple manual manipulation techniques have also been created for the remaining cases. These advancements are projected to considerably influence nuclear cardiology by reducing the time necessary for study analysis and evaluation, influencing both technical and physician expenses.
Furthermore, this method is predicted to increase the repeatability of myocardial perfusion SPECT. Many types of software can use to assess cardiac function as research said but we are use one type of software which is Cedar-Sinai QGS software [Diagnostic evaluation of three cardiac software packages using a consecutive group of patients]. In Cedar-Sinai QGS software allow using automated and manual processes. It is important to use manual processing to make sure that the placement of the organ specifically cardiac borders is accurate and can be verify the region of interest (ROI) and also to minimized the artifact from adjacent organ to the heart borders like a big breast or diaphragm [QGS+QPS Automatic Quantification Version 2013.1]. Some research says that the artifacts has a minor effect, but do not cause a significant impact on the study [Diagnostic evaluation of three cardiac software packages using a consecutive group of patients]. Despite that, we found in this research that patients who have potential artifacts related to patient or technical factors are more in need of manual processing to increase the accuracy of the cardiac volume and ejection fraction [Artifacts in Quantitative analysis of myocardial perfusion SPECT, using Cedars-Sinai QPS Software].

Conclusion

We found discrepancies that exist by using the fully automated and manual technique for determining LVEF and volumes by gated MPI. This study highlights the importance of a semi-automated technique using a mix of automated and manual correction of LV contours to ensure a more precise and accurate estimation of Left ventricular function. Semi-automated processing is important to improve the results, thus minimizing the potential impact on diagnosis and patient management.

Limitations

The population of the patients used in this study was small hence larger set of data is required for more in-depth analysis. Other limitation that we have only one computer of Siemens E-cam and Symbia SPECT systems using for processing. The software for the device is updated at the end of each month, and from this point of view, additional information such as manual processing which is not needed by every patient and is considered overload on the device so that why deleted.

Recommendations

The operator always should be alert to myocardial boundaries (LV epicardial and endocardial contours and apex/base endpoints) that do not look correct or mismatched to visual assessment, especially in centers lacking a newer SPECT-CT system (equipped with CT attenuation correction option).

Abbreviations

SPECT: single-photon emission computed tomography; LVEF: Left ventricular ejection fraction; EF: Ejection fraction; EV: Ejection volume; EDV: End-diastolic volume; ESV: End-systolic volume; QGS: Quantitative gated SPECT; CT: computed tomography; TID: Transient Ischemic Dilation; MPI: Myocardial perfusion imaging; MUGA: Multi-gated cardiac blood pool acquisition; MRI: Magnetic resonance imaging; CMR: Cardiac Magnetic Resonance.

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Availability of data and materials

All data analyzed during this research are included in this article.

Declarations

Informed consent

The data were collected electronically from the computer with full consent from participants as they started with informed consent then oral questions before doing the examination, which was agreed upon as a willingness to participate in the study. In order to protect the privacy of participants, all details will be obtained anonymously.

Ethical Approval

This study has been reviewed and approved by the Research Ethics committee (REC) at the university of Hail (Research # H-2022-114).

Competing interests

The authors declare that they have no competing interests.
References


