Accuracy of Visual Assessment in the Detection and Quantification of Myocardial Scar by Delayed Enhancement Magnetic Resonance Imaging

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Background: *Delayed-enhancement magnetic resonance imaging (DE-MRI) is now a standard for the detection of myocardial scar and viability. Standard analysis needs expensive software.*
Objective: *To determine the accuracy of visual assessment in the detection and quantification of myocardial scar by DE-MRI technique.*
Material and Method: *The authors enrolled 32 patients with coronary artery disease (CAD) as documented by coronary angiography (CAG) and left ventricular dysfunction. All patients underwent cardiac magnetic resonance imaging for the assessment of global and regional myocardial function and DE-MRI. The presence and amount of scar in each myocardial segment was assessed by standard method. Visual assessment was performed by two methods: 1) visual drawing of the boundary of the hyperenhancement region and calculation of percentages of scar in an individual segment 2) visual estimation of grading of hyperenhancement area from 0 (no scar) to 4 (>75% scar). The agreement for scar detection and correlation of scar quantification for individual segments were evaluated.*
Results: *Thirty-one of 32 patients in the present study had myocardial scar. One thousand four hundred athirty two myocardial segments were analyzed. Visual detection of myocardial scar has an excellent level of agreement with standard method of scar (Kappa = 0.963 and 0.952, p < 0.001 for visual method I and II). Visual method I and II has an accuracy of 98.2% and 97.6% respectively in the detection of myocardial scar compared to standard method. Percentages of myocardial scar in each myocardial segment by visual method I correlate very well with standard method (Intraclass Correlation Coefficient = 0.885). Visual grading of amount of myocardial scar also has an excellent correlation with standard method (Spearman rank correlation coefficient = 0.934).*
Conclusion: *Visual assessment of myocardial scar is accurate for the detection and quantification of scar.*

Keywords: *Magnetic resonance imaging, Delayed enhancement, Myocardial scar, Visual assessment*

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Presence and amount of myocardial scar are important data not only for diagnostic purposes but also for providing prognosis and guiding therapy. Delayed-enhancement magnetic resonance imaging (DE-MRI) is the gold standard for the detection of myocardial scar and viability(1). DE-MRI is very accurate in the detection of myocardial scar compared to nuclear imaging both in the patients after myocardial infarction(2) and in animal models compared to the gold standard of myocardial scar by histopathology(3). Magnetic resonance imaging (MRI) can also provide other informa-

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tion on global and regional myocardial function in the same session. Combined information on cardiac function and myocardial viability is useful for guiding treatment and determining whether revascularization will have any beneficial effects on the improvement of myocardial function in an individual patient[4]. Regional and global improvement of myocardial function has been shown to directly relate to the amount of viable myocardium detected by DE-MRI. Recently, it has been shown that presence of myocardial scar indicated by DE-MRI is an independent prognostic data in patients with symptom or sign of coronary artery disease (CAD)[5].

Standard assessment technique for myocardial scar has been shown to be very accurate and highly reproducible in many studies[6,7]. However, this technique needed special software to calculate hyperenhancement area according to multiple of standard deviation of signal intensity above the normal myocardium in remote regions. This software is very expensive and therefore is of limited availability. It is used mainly in research institutes and for research purposes. Visual assessment of myocardial scar can be performed by visual drawing of boundary of myocardial scar and then calculation of ratio of scar to segment area in each myocardial segment. This technique is time-consuming. Another method of visual estimation can be performed by the grading of proportion of scar area to segment area, which is much less time-consuming. There has been no previous report on the comparison of the visual estimation with the standard method.

The objectives of the present study were to determine accuracy of the two methods of visual estimation in the detection and quantification of myocardial scar for each myocardial segment as compared to the standard technique.

Material and Method

Study population

Inclusion criteria of the present study were male or female more than 30 years of age with coronary artery disease documented by coronary angiography (CAG) and left ventricular dysfunction defined as left ventricular ejection fraction (LVEF) less than 50%. Exclusion criteria were 1) contraindication to MRI such as pacemaker or defibrillator implantation, intracranial clips or ferromagnetic material implantation or history of claustrophobia or allergy to gadolinium 2) requiring urgent revascularization 3) unstable hemodynamic. The present study was approved by the Ethics Committee of Siriraj Hospital. Informed consent was obtained from all patients prior to participation.

Cardiac MRI

All patients underwent cardiac MRI. Cardiac MRI was performed by the Gyroscan NT Intera 1.5 Tesla Philips scanner (Philips Medical System, Best, the Netherlands). Cardiac MRI was started with gradient echo technique for the assessment of global and regional myocardial function in long axis, 2-chamber, 4-chamber, and multiple slice short axis view for the whole left ventricle. DE-MRI was then performed by an injection of 0.2 mmol/kg of gadolinium (Magnevist,

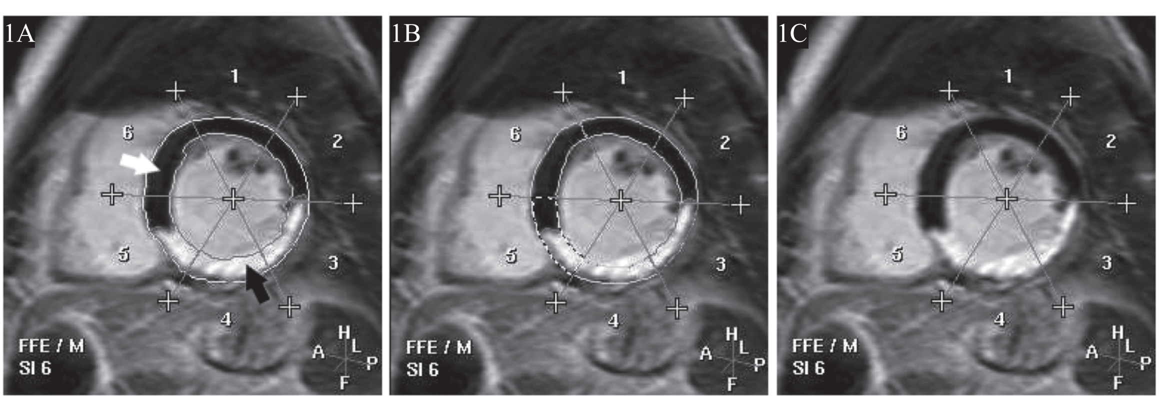

Fig. 1 DE-MRI images during analysis by standard method (1a), visual method I by visual drawing of boundary of scar and segment area (1b) and visual method II by visual grading of proportion of myocardial scar in each segment (1c), white arrow shows normal myocardium whereas black arrow shows scarred myocardium

Table 1. Baseline characteristics

Characteristics	Number (%) or Mean ± SD
Age (yrs)	62.7 ± 8.7
Male gender	29 (90.6)
Diabetes mellitus	13 (40.6)
Systemic hypertension	19 (59.4)
Cigarette smoking	15 (46.9)
Hypercholesterolemia	29 (90.6)
History of myocardial infarction	20 (62.5)
History of heart failure	27 (84.4)
History of PCI	5 (15.6)
Angina pectoris	27 (84.4)
NYHA functional class	
I	2 (6.3)
II	21 (65.6)
III	9 (28.1)
Q-wave from ECG	13 (40.6)

PCI = percutaneous coronary intervention, SD = standard deviation

Schering AG, Berlin, Germany) followed by imaging of hyperenhancement area 7-10 minutes after the injection. Inversion time was adjusted to null normal myocardium so that normal myocardium appears black on the image and scar myocardium appears white on the image. DE-MRI images was assessed in multiple slice short axis, 2-chamber and 4-chamber view. The same levels of short-axis slice were acquired for functional study and DE-MRI. The images were acquired with the use of 3D segmented-gradient-echo inversion-recovery sequence with TE 1.25, TR 4.1, 15 degree flip angle, 303x 384 mm field of view, 240 x 256 matrix, in-plane resolution 1.26x1.5 mm, slice thickness of 8 mm and 1.5 SENSE factor. The whole procedure takes approximately 40 minutes.

Analysis of MRI images

Image analysis was performed on an independent Easy Vision workstation. MRI images in short-axis view were classified into the basal, mid or apical part of the left ventricle. Segmentation of each slice was performed according to recommendation of American Heart Association with the exclusion of segment 17 (most apical part)[8]. MRI images in the basal and mid part of left ventricle were divided into 6 segments per slice and those in the apical part were divided into 4 segments per slice. First segment of each slice started at anterior insertion site of right ventricular wall to left ventricular wall. Segments with suboptimal image quality were excluded from analysis. Wall motion of each myocardial segment before and after CABG was recorded as 5-grade system as follows: 1 = normal, 2 = mild or moderate hypokinesia, 3 = severe hypokinesia, 4 = akinesia, or 5 = dyskinesia. Left ventricular ejection fraction was assessed by using end-systolic and end-diastolic volume calculated from the multiple slice short axis images.

Epicardial, endocardial contours and hyperenhancement areas in each of the short-axis images were manually delineated. Presence and amount of scar in each myocardial segment was assessed by standard techniques using a computer-assisted detection analysis, by defining a hyperenhancement area as an increase in signal intensity more than 2 standard deviations above the signal intensity of a remote myocardial region (Fig. 1a). Visual assessment was performed by two methods: 1) visual drawing of boundary of hyperenhancement region and calculation of ratio of hyperenhanced area to total myocardial area of the individual myocardial segment (Fig. 1b) 2) visual estimation of grading of hyperenhancement area (Fig. 1c) by classification of each myocardial segment into 5 grade; 0 = no hyperenhancement area, grade 1-4 = hyperenhancement area 0.1-25%, 25.1-50%, 50.1-75%, and 75.1-100% respectively. Each measurement was performed by two interpreters and was performed separately by each when unaware of the patient's data and results of other measurements.

Statistical analysis

Continuous variables were described as mean ± standard deviation (SD) and categorical variables were described as frequencies and percentages.

Presence of myocardial scar by two methods of visual assessment was compared to standard technique and compared to each other by Kappa analysis. Quantification of myocardial scar by two methods of visual assessment was compared to the standard technique by Intraclass Correlation Coefficient and Bland-Altman analysis for percentages of myocardial scar and the Spearman rank analysis for grading of myocardial scar.

In all tests, the criterion for statistical significance was two-sided $p \leq 0.05$.

Results

Thirty-two patients were enrolled. Baseline characteristics are shown in Table 1. Coronary angiogram revealed double and triple vessel disease in six (18.8%) and 26 (81.3%) respectively. Table 2 shows left

Table 2. Functional MRI parameters

Parameters	Mean ± SD
LVEDD (mm)	60.9 ± 9.9
LVESD (mm)	49.9 ± 11.4
LVEDV (mL)	179 ± 73.8
LVESV (mL)	113.3 ± 68.6
LV mass (gram)	122.6 ± 38
LVSV (mL)	66.6 ± 15.8
LVEF (%)	40.1 ± 12.9

LVDD = left ventricular diastolic diameter, LVDS =left ventricular systolic diameter, LVEDV = left ventricular end-diastolic volume, LVESV = left ventricular end-systolic volume, LVSV = left ventricular stroke volume, LVEF = left ventricular ejection fraction

ventricular size and volume during end-diastole and end-systole and ejection fraction.

Agreement between the two visual methods and standard method for the detection of myocardial scar (visual method I and II versus standard method)

Hyperenhancement was detected in 31 out of 32 patients (96.9%). After excluding 36 segments with inadequate image quality, there were 1432 myocardial segments. Hyperenhancement was detected in 646 segments (45.1%) by standard method and 662 (46.2%) and 666 segments (46.5%) by visual method I and II respectively. Visual method I and II had an excellent agreement with the standard method (Kappa = 0.963, $p < 0.001$ for visual method I and Kappa = 0.952, $p < 0.001$ for visual method II). Sensitivity and specificity and accuracy of visual method I and II in the detection of scar compared to the standard method are shown in Table 3.

Correlation between visual method and standard method for quantitative analysis of percentages of myocardial scar (visual method I versus standard method)

Six hundred and forty-one myocardial segments had evidence of hyperenhancement by both standard method and visual method I. Intraclass correlation coefficient analysis which analyzed both correlation and precision of their nominal values demonstrated a significant correlation between standard method and visual method I for the percentages of myocardial scar (ICC = 0.885, $p < 0.001$)(Fig. 2). However, Bland-Altman analysis showed that visual method I tended to overestimate percentages of scar by an average of 4 ± 16%.

Correlation between visual method and standard method for quantitative analysis of grading of myocardial scar (visual method II versus standard method)

Myocardial scar grade 0, 1, 2, 3, and 4 was detected by visual method II in 766 (53.5%), 203 (14.2%), 202 (14.1%), 151 (10.5%), and 110 (7.7%) myocardial segments respectively. For comparison purpose, percentages of myocardial scar by standard method were graded by the same rule. Results of analysis demonstrated that 786 (54.9%), 121 (8.4%), 236 (16.5%), 170 (11.9%), and 119 (8.3%) myocardial segments were classified into grade 0, 1, 2, 3 and 4 respectively. Spearman rank correlation analysis showed an excellent correlation coefficient of 0.934 with a p value < 0.001 between myocardial scar grading by visual and standard method. If the authors grade percentages of scar area by visual method I and make correlation of scar grading by visual method I and II, the authors will have a perfect correlation with the Spearman rank correlation coefficient of 0.933, $p < 0.0001$.

Discussion

The authors have demonstrated that almost all patients with CAD and significant left ventricular systolic dysfunction have myocardial scaring when imaged by DE-MRI method. Visual detection of myocardial scar has an excellent level of agreement with standard detection of scar. Percentages of myocardial scar in each myocardial segment by visual drawing of scar and segmental boundary correlate very well with standard method. Visual grading of amount of myocardial scar also has an excellent correlation with standard method.

There are several methods for the assessment of myocardial viability. Nuclear study such as positron emission tomography (PET) and thallium scan has been used for many decades(2,9). Although PET scan has been considered a gold standard, it has a very limited availability due to its expensive cost. Thallium scan can provide ischemia and viability information in the same study. It has been shown that thallium reinjection or 24-hour delayed image may be required in order to have a better image quality of scar(10). However, it has a suboptimal sensitivity for the detection of myocardial scar, especially subendocardial scar, which is a very common type of scar(2,3). Moreover, patients have to

Table 3. Diagnostic accuracy of visual method I and II for the detection of myocardial scar compared to standard method

	Visual Method I	Visual Method II
True positive	641	639
True negative	765	759
False positive	21	27
False negative	5	7
Sensitivity (%)(95%CI)	99.2 (98.2-99.7)	98.9 (97.8-99.5)
Specificity (%)(95%CI)	97.3 (96-98.2)	96.6 (95-97.6)
Positive predictive value (%)	96.8 (95.2-97.9)	95.9 (94.2-97.2)
Negative predictive value (%)	99.4 (98.5-99.7)	99.1 (98.1-99.6)
Accuracy (%)	98.2	97.6
Prevalence (%)	45.1	45.1

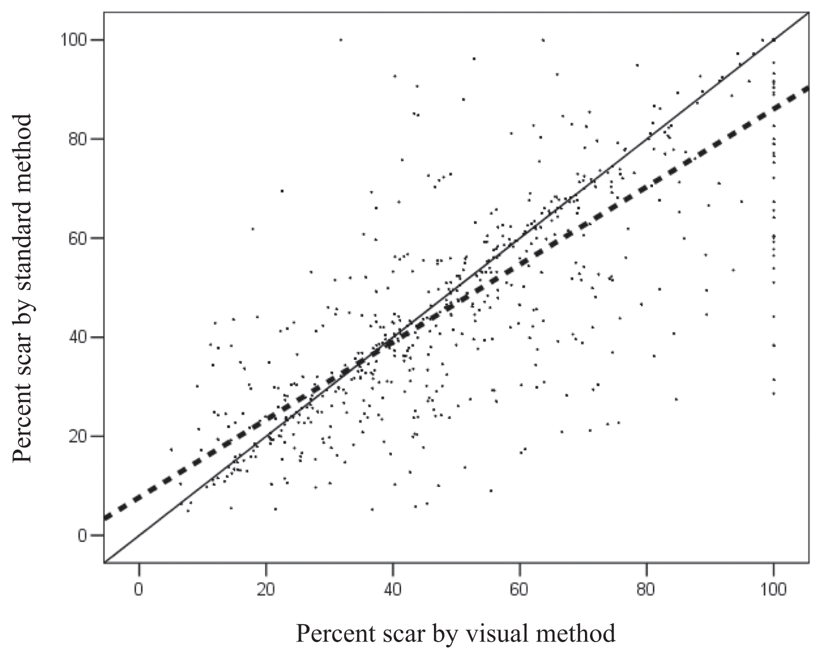

Fig. 2 Correlation between percentages of scar in each segment by standard method and visual method I

be exposed to a significant amount of radiation with this nuclear study. Other methods for the assessment of myocardial viability are MRI or dobutamine echocardiography. Dobutamine echocardiography can give information of ischemia by the observation of new or worsening wall motion during stress. By the use of low dose dobutamine, the authors can also assess myocardial viability of the dysfunctional myocardial segments[11]. However, many patients such as obese patients or those with chronic lung disease will have a poor echocardiographic window resulting in poor image resolution, which will compromise the accuracy of the interpretation[12].

MRI can assess myocardial viability by the dobutamine stress MRI, which has a good chance of having a better image resolution compared to echocardiogram[12]. Another MRI method is by the use of DE-MRI which is a more widely used method compared to dobutamine MRI. After an injection of gadolinium, the contrast will rapidly diffuse from the intravascular to the extracellular space. Area with altered sarcolemmal membrane integrity and expansion of extracellular matrix structure will be enhanced when the image was acquired 7-10 minutes after the injection, whereas gadolinium in the normal myocardial area already washed out before that time[1]. With this method, myocardial scar can be clearly demonstrated. Kim et al demonstrated that hyperenhancement area discovered by DE-MRI matched with that of myocardial scar from histopathological specimen in animal model[13]. He also demonstrated that amount of scar by DE-MRI can be used to predict improvement of regional wall motion after revascularization[4]. DE-MRI can therefore be used to select which patients will benefit from revascularization and which vessel should be revascularized. It has been reported, in animal models, by the use of histopathology as the gold standard, that DE-MRI can detect more than 90% of subendocardial scar compared to approximately only half by thallium scan[3]. Amount of scar detected by DE-MRI has also been shown to be highly reproducible[7].

Accurate quantification of myocardial scar by DE-MRI requires special software that can adjust threshold detection of scar that will be at least 2 standard deviations above nonenhanced myocardium[14]. This type of software is very expensive. Percentages of scar in each myocardial segment can be assessed by visual drawing of the scar and segmental boundary and calculation of percentages of scar in each individual segment. This technique is time consuming. Therefore, the authors attempted to make analysis by visual grading of amount of scar by dividing it into 5 grades, from 0 to 4, which is also a widely used classification that has been reported in clinical trials[4,15]. This method is less time consuming and if accurate will become an easily used technique for the assessment of myocardial viability without the need for special software. The authors showed that visual method I and II has an accuracy of 98.2% and 97.6% respectively in the detection of myocardial scar compared to standard method.

Although the authors demonstrated that percentages of scar by visual assessment correlate very well with the standard method, the visual method tends to overestimate amount of scar by an average of 4%. This finding may be related to a discrepancy in defining area of scar around the transitional area between scar and normal myocardial area. The authors also found that visual grading of amount of scar had a significant correlation with grading by standard method. One point to be remembered for visual estimation is that, although DE-MRI images can nicely demonstrate area of scar, experience of image analysis may be required. In the present study, all interpretators had at least 3 years experience in cardiac MRI.

In conclusion, visual assessment of myocardial scar is accurate for the detection and quantification of scar. Visual estimation of amount of scar can be confidently performed in terms of scar percentages or grading.

References

1. Thomson LE, Kim RJ, Judd RM. Magnetic resonance imaging for the assessment of myocardial viability. J Magn Reson Imaging 2004; 19: 771-88.
2. Ibrahim T, Bulow HP, Hackl T, Hornke M, Nekolla SG, Breuer M, et al. Diagnostic value of contrast-enhanced magnetic resonance imaging and single-photon emission computed tomography for detection of myocardial necrosis early after acute myocardial infarction. J Am Coll Cardiol 2007; 49: 208-16.
3. Wagner A, Mahrholdt H, Holly TA, Elliott MD, Regenfus M, Parker M, et al. Contrast-enhanced MRI and routine single photon emission computed tomography (SPECT) perfusion imaging for detection of subendocardial myocardial infarcts: an imaging study. Lancet 2003; 361: 374-9.
4. Kim RJ, Wu E, Rafael A, Chen EL, Parker MA, Simonetti O, et al. The use of contrast-enhanced magnetic resonance imaging to identify reversible myocardial dysfunction. N Engl J Med 2000; 343: 1445-53.
5. Kwong RY, Chan AK, Brown KA, Chan CW, Reynolds HG, Tsang S, et al. Impact of unrecognized myocardial scar detected by cardiac magnetic resonance imaging on event-free survival in patients presenting with signs or symptoms of coronary artery disease. Circulation 2006; 113: 2733-43.
6. Mahrholdt H, Wagner A, Holly TA, Elliott MD, Bonow RO, Kim RJ, et al. Reproducibility of chronic infarct size measurement by contrast- enhanced magnetic resonance imaging. Circulation 2002; 106: 2322-7.
7. Bulow H, Klein C, Kuehn I, Hollweck R, Nekolla SG, Schreiber K, et al. Cardiac magnetic resonance imaging: long term reproducibility of the late enhancement signal in patients with chronic coronary artery disease. Heart 2005; 91: 1158-63.
8. Cerqueira MD, Weissman NJ, Dilsizian V, Jacobs

AK, Kaul S, Laskey WK, et al. Standardized myocardial segmentation and nomenclature for tomographic imaging of the heart. A statement for healthcare professionals from the Cardiac Imaging Committee of the Council on Clinical Cardiology of the American Heart Association. Int J Cardiovasc Imaging 2002; 18: 539-42.

9. Tarakji KG, Brunken R, McCarthy PM, Al Chekakie MO, Abdel-Latif A, Pothier CE, et al. Myocardial viability testing and the effect of early intervention in patients with advanced left ventricular systolic dysfunction. Circulation 2006; 113: 230-7.

10. Dilsizian V, Rocco TP, Freedman NM, Leon MB, Bonow RO. Enhanced detection of ischemic but viable myocardium by the reinjection of thallium after stress-redistribution imaging. N Engl J Med 1990; 323: 141-6.

11. Afridi I, Grayburn PA, Panza JA, Oh JK, Zoghbi WA, Marwick TH. Myocardial viability during dobutamine echocardiography predicts survival in patients with coronary artery disease and severe left ventricular systolic dysfunction. J Am Coll Cardiol 1998; 32: 921-6.

12. Nagel E, Lehmkuhl HB, Bocksch W, Klein C, Vogel U, Frantz E, et al. Noninvasive diagnosis of ischemia-induced wall motion abnormalities with the use of high-dose dobutamine stress MRI: comparison with dobutamine stress echocardiography. Circulation 1999; 99: 763-70.

13. Kim RJ, Fieno DS, Parrish TB, Harris K, Chen EL, Simonetti O, et al. Relationship of MRI delayed contrast enhancement to irreversible injury, infarct age, and contractile function. Circulation 1999; 100: 1992-2002.

14. Tatli S, Zou KH, Fruitman M, Reynolds HG, Foo T, Kwong R, et al. Three-dimensional magnetic resonance imaging technique for myocardial-delayed hyperenhancement: a comparison with the two-dimensional technique. J Magn Reson Imaging 2004; 20: 378-82.

15. Ingkanisorn WP, Rhoads KL, Aletras AH, Kellman P, Arai AE. Gadolinium delayed enhancement cardiovascular magnetic resonance correlates with clinical measures of myocardial infarction. J Am Coll Cardiol 2004; 43: 2253-9.

ความแม่นยำของการวิเคราะห์ภาพกล้ามเนื้อหัวใจตายจากการตรวจสนามแม่เหล็กไฟฟ้าด้วยสายตาเทียบกับวิธีมาตรฐาน

รุ่งโรจน์ กฤตยพงษ์, ไพรัช สายวิรุณพร, ธนัญญา บุณยศิรินันท์, สุภาพร นาคเย็น, ประจักษ์ ธนพิบูลย์ผล, สุทธิพล อุดมพันธุรัก

ภูมิหลัง: *ปัจจุบันการตรวจหัวใจด้วยสนามแม่เหล็กเป็นวิธีมาตรฐานในการประเมินรอยแผลเป็นที่กล้ามเนื้อหัวใจ โปรแกรมมาตรฐานในการวิเคราะห์ข้อมูลมีราคาแพง*

วัตถุประสงค์ : *เพื่อประเมินความแม่นยำของการวินิจฉัยและการตรวจวัดปริมาณรอยแผลเป็นของหัวใจด้วยสายตาเทียบกับวิธีมาตรฐาน*

วัสดุและวิธีการ: *คณะผู้วิจัยได้ศึกษาผู้ป่วย 32 ราย ที่ได้รับการวินิจฉัยเป็นโรคเส้นเลือดหัวใจตีบร่วมกับมีการทำงานของหัวใจห้องล่างซ้ายผิดปกติ ผู้ป่วยได้รับการตรวจหัวใจด้วยสนามแม่เหล็กเพื่อประเมินการทำงานของหัวใจ และตรวจ รอยแผลเป็นที่กล้ามเนื้อหัวใจ การวินิจฉัยและวัดปริมาณของรอยแผลเป็นทำโดยวิธีมาตรฐานและวิธีใช้สายตา ซึ่งทำ 2 แบบ คือใช้วิธีลากเส้นขอบเขตของรอยแผลเป็นและขอบเขตของกล้ามเนื้อหัวใจในแต่ละส่วนของกล้ามเนื้อหัวใจและเทียบเป็นร้อยละ อีกแบบหนึ่งประเมินโดยแบ่งปริมาณรอยแผลเป็น เป็น 5 ระดับตั้งแต่ 0 คือไม่มีเลย ถึง 4 คือมีรอยแผลเป็นเกิน 75% ในผนังหัวใจส่วนนั้น คณะผู้วิจัยวิเคราะห์ความแม่นยำของการวินิจฉัยรอยแผลเป็นด้วยสายตาและความสัมพันธ์ของการวัดปริมาณรอยแผลเป็นด้วยสายตาเทียบกับวิธีมาตรฐาน*

ผลการศึกษา: *ผู้ป่วย 31 รายใน 32 ราย มีรอยแผลเป็น สามารถแบ่งผนังหัวใจของผู้ป่วยทั้งหมดเป็น 1,432 ส่วน ความแม่นยำของการวิเคราะห์ด้วยสายตาทั้ง 2 วิธีในการวินิจฉัยรอยแผลเป็น เป็น 98.2% และ 97.6% โดยมีค่า Kappa = 0.963 การวินิจฉัยด้วยสายตา ให้ค่าร้อยละของรอยแผลเป็นในหัวใจแต่ละส่วนใกล้เคียงกับวิธีมาตรฐาน โดยค่า Intraclass Correlation Coefficient (ICC) เป็น 0.885 การแบ่งระดับปริมาณของรอยแผลเป็นด้วยสายตามีความสัมพันธ์กับการตรวจวิธีมาตรฐาน โดยค่า Spearmen Coefficient เป็น 0.934*

สรุป: *การประเมินรอยแผลเป็นด้วยสายตาให้ความแม่นยำสูงในการวินิจฉัยรอยแผลเป็นและวัดปริมาณรอยแผลเป็นที่กล้ามเนื้อหัวใจ*