Study on factors affecting local peak strain results in automatic functional imaging of transthoracic echocardiography

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Background: To investigate the important impacting factors on the accuracy of local peak strain (RLS) in transthoracic echocardiography real-time tri-axial automatic functional imaging (AFI), to evaluate the clinical efficacy of AFI and to improve the accuracy of the results.

Methods: From May 2016 to May 2017, 82 healthy volunteers were enrolled in the AFI examination, of which 22 were excluded and 60 were eligible. The excluded 22 patients were analyzed for exclusion reasons, and the results of the 60 eligible AFI results were studied focusing on the longitudinal left ventricular regional longitudinal peak systolic strain (RLS) in different methods of operation, to compare the results and accuracies of AFI by different influencing factors, and to find the most important ones.

Results: The success rate of AFI for this group of subjects is 74%, and the exclusion reason is that the left ventricular segments cannot be fully displayed. Among eligible subjects, the main influencing factors on RLS were region of interest (ROI), aortic valve closure time adjustment and image frame rate selection. The differences of results obtained by different operations were statistically significant ($P<0.05$).

Conclusions: The success rate of AFI for this group of subjects is 74%. The RLS results were influenced by multiple factors, which can be effectively avoided.

Keywords: Automatic functional imaging (AFI); regional longitudinal peak systolic strain results (RLS results); influencing factors; accuracy

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Introduction

Two-dimensional speckle tracking (2DST) technology is an ultrasound quantitative analysis tool developed in recent years. It can accurately evaluate local and global myocardial motion and play an important role in the cardiovascular field (1). The real-time tri-plane automatic functional imaging (AFI) technology is a 2DST imaging technique that simultaneously displays three sections on the same phase of the same cardiac cycle and directly quantifies the local myocardial contractile function, and reflects the speed gradient or velocity of the unit myocardial length. The spatial distribution of gradients is only related to the relative velocity, and is not affected by the overall heart movement and the adjacent segmental traction, and can more truly reflect the functional status of the regional myocardium. Automated functional imaging is a tool for assessing left ventricular segmental systolic function (2). It collects images of different sections of the ventricle and processes it through computer processing. It is displayed in the form of bull's eye analysis charts, curves, and fractions. The color-coded value of peak longitudinal strain at systole. Its advantage is that it can visually show the contraction function and strain condition of the left ventricular wall segments (3). It is simple to use and has good clinical value. However, the accuracy of the regional longitudinal peak systolic strain (RLS) in the AFI test results is affected by many factors. Therefore, it is important to find and analyze the important factors affecting the RLS results in our study, and it can be used for future clinical work guidance role.

Methods

Normal information

A total of 82 healthy volunteers recruited in our hospital from May 2016 to May 2017 were selected for examination. The age ranged from 20 to 65. The gender ratio was 3:5 and the median age was 41. Inclusion criteria: all subjects had normal ECG examination. And rule out any other heart disease. Exclusion criteria: unnormal ECG examination. And heart disease patients.

Inspection method

Using GE Vivid E9 ultrasonic diagnostic apparatus, equipped with M5S probe with frequency of 1.5–4.6 MHz and 4V probe with frequency of 1.5–4.0 MHz. All patients were kept in left lateral position; the ECG were simultaneous recorded; M5S probe was used for routine measurement; In exchange for a 4V probe, after acquiring a standard apical 4-chamber view, start the Multi-D key to enter the Triplane mode, adjust the frame rate, acquire and store images in four consecutive cardiac cycles; Perform an AFI analysis on the penultimate cardiac cycle-the system automatically analyzes and tracks myocardial motion in the region of interest and gives analysis of each segment of the left ventricular wall. Successful segments appear to be acceptable (√), unsuccessful segments show unacceptable (×). If the tracking is poor, manual adjustment will be performed until the system obtains the successful segments and the corresponding graphs, Bull's eye analysis chart of the segments and the whole Left ventricular wall longitudinal strain will be automatically displayed (the left ventricular wall partitioning method adopts 17 segments law).

Research definition

This study defines: when the left ventricular chase quality is rated as unacceptable (×) segment is greater than 1 segment is removed. Twenty-two cases were excluded, and the reasons for the elimination were found and analyzed. The RLS results of 60 patients were compared under different operating conditions. Long-term clinical practices and pre-studies prove that the base point and vertex positioning, aortic valve closure time and frame rate may have a great impact on the results, which marks as the starting point of this study. Respectively, we used different trajectory descriptions, deviations of the base point and the vertex to define the distance of 0.5 cm from the normal positioning point. We used different aortic valve closing time (aortic valve closure timing deviation is delayed and advanced by more than one frame); The frame rate we used were 38/s and 50 frames/s. We analyzed and compared our results with the accurate RLS results.

Statistical analysis

We used SPSS18.0 statistical software with measurement data being displayed as (mean ± SD). The comparison of measurement data between groups are through variance analysis, and different comparison methods are used for the same individual with paired sample *t*-test (the hypothesis testing level is set as 0.05). We conducted comparative analyses of different methods of operation if $P<0.05$, then the difference was statistically significant.

Results

In the analysis of conventional AFI results for this study, the elimination rate was 26% and the success rate was 74%. The percentage of data rejection is 26%. The RLS results of the 74% successful subjects show that the RLS values of the mid-segment are always the largest regardless of methods adopted. The correct RLS values of ROI in apex-mid-basis segment are greater than the wrong ones. If the aortic valve closure time is delayed for more than 1 frame, the RLS values of apex-mid-basis segment are lower than normal values, and

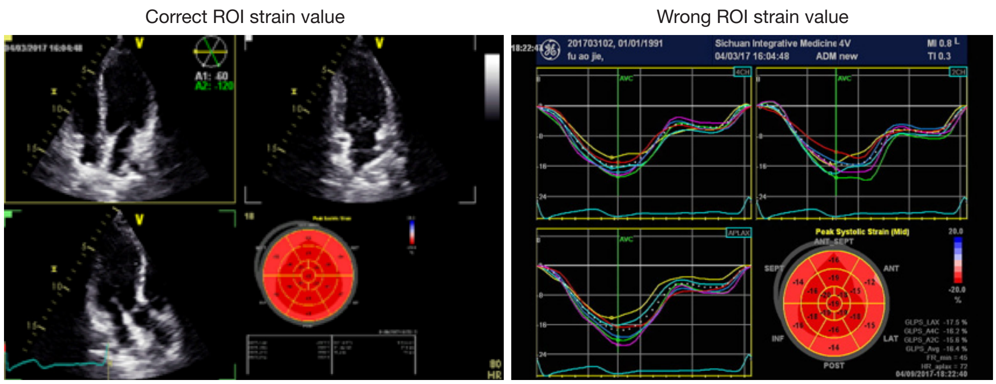

Figure 1 Different ROI definition curves. ROI, region of interest.

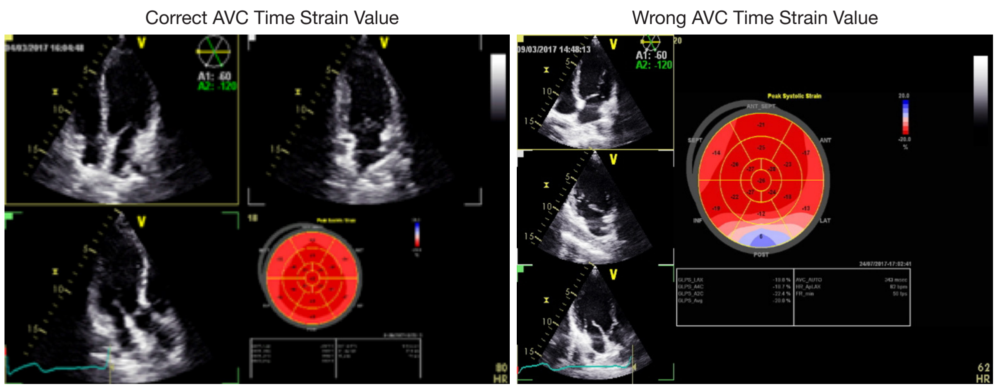

Figure 2 Different AVC timing mediations. AVC, aortic valve closure.

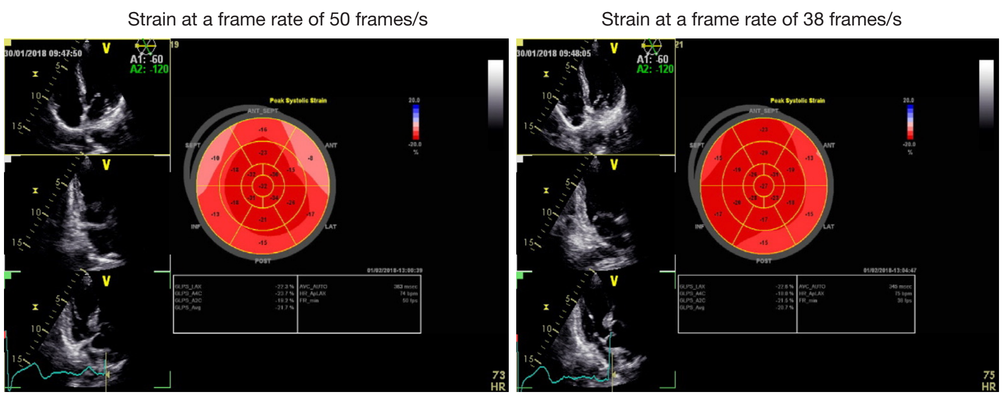

Figure 3 Different frame rates.

if the aortic valve closure time is advanced for more than 1 frame, the RLS values of apex-mid-basis segment are higher than normal values. The results were statistically significant, P<0.05. The image frame frequency was selected between 40 and 80 frames. When the frame rate is below 40 (4), only the difference of the apex strain is statistically significant. The differences of the strain between the basal segment and the middle segment are not statistically significant.

The results of the analysis are shown in the following *Figures 1-3*, and *Tables 1-3*.

Table 1 RLS comparison table with different ROI definition curves

Segment	Strain peak 1 (accurate ROI curve)	Strain peak 2 (ROI curve with deviation)
Apex segment	28.23±4.76	24.51±5.05
Mid segment	20.17±4.27	16.67±4.83
Basis segment	15.11±4.66	12.36±3.32

P<0.05. RLS, regional longitudinal peak systolic strain; ROI, region of interest.

Table 2 Comparison of RLS at different AVC timing mediations

Segment	Strain peak 1 (accurate AVC timing mediation)	Strain peak 2 (delayed AVC timing mediation)
Apex segment	28.23±4.76	23.10±5.61
Mid segment	20.17±4.27	15.28±5.73
Basis segment	15.11±4.66	12.02±4.81

P<0.05. RLS, regional longitudinal peak systolic strain; AVC, aortic valve closure.

Table 3 RLS comparison table at different frame rates

Segment	Strain peak 1 (frame rate 50/S)	Strain peak 2 (frame rate 38/S)	P
Apex segment	28.23±4.76	23.13±5.14	<0.05
Mid segment	20.17±4.27	18.72±4.14	>0.05
Basis segment	15.11±4.66	15.33±4.17	>0.05

RLS, regional longitudinal peak systolic strain.

Discussions

2DST technology is to track a specific point in the ventricular wall in real time, and automatically calculate the description of the amplitude and trajectory. Real-time triad AFI is a new 2DST technique, it is a fast and easy analytical technique based on 2DST imaging. It has no angle dependence, simple operation and good repeatability (5). It provides myocardial tissue strain bovine eye diagram with different colors to identify the strain of the left ventricular segment. The size can intuitively reflect the change in systolic function of the left ventricular wall segment. Compared with the original tissue Doppler imaging technique for evaluating myocardial deformability (6), it is of high temporal resolution with no influence by the sound beam angle; it can clearly display the myocardial motion; it can quickly and accurately obtain various strain values of the left ventricular wall through standardized calculation software. It is mainly used to evaluate the peak longitudinal myocardial systolic strain, and is a reliable tool to evaluate longitudinal left ventricle systolic function (7).

In this trial, the clinical efficiency of AFI was 74%. We found that auto-imaging was not suitable for all subjects. When the lung-air interference was particularly heavy or the sound-transmission window due to body size was insufficient (such as chronic bronchitis, emphysema, and thin body type), can not get a clear standard display of the ventricle, it can not be effective results were removed, the elimination rate of 26%, among which 6 volunteers was found to be unqualified in the initial phase who later changed from the original left lateral position to the prone lateral position and as a result, all the segments have become acceptable. The reason is that the heart gets closer to the chest wall and the probe, making it clearer to display (8), thus increasing the image display rate. Similarly, breathing also affects the quality of the image-take a deep breath will increase the lung image interference, and slow breathing can stabilize the image. We can improve the image quality by adjusting how the lung covers the ventricle. Therefore, at this time, the patient may be instructed to change the breathing mode, and the image is collected when the end-expiratory breath-hold method is used to achieve the best effect of the image display so as to improve the efficiency of the AFI examination and the accuracy of the result (9). Among the qualified cases, the accuracy of the RLS results is mainly affected by the following factors.

Influence of endocardial trajectory tracing (ROI)

We found in the analysis that the definition of ROI is very important. When the ROI is automatically defined, it is often impossible to achieve satisfactory results, and a small number of segments cannot be perfectly recognized by the machine. This requires us to manually compensate, and when manually compensating or manually defining the ROI, the fixed-point position is crucial. From *Table 1* it can be seen that the peak strain in the apical segment is the largest in both descriptive methods, but in the wrong description, the strain values in the apical, middle, and basal segments are lower than normal (10). If the base point is placed too far from the annulus region, the ROI segment at the base of the annulus will not move along with its source 2D image during the entire cardiac cycle, resulting in the measured local strain value being too low or the image being unidentifiable. In addition, the base point cannot be placed in the aorta, otherwise the recording data of the aortic movement will also appear lower than normal (11). When placed at the apex, the ROI line should cover the myocardium. If the apex is placed too high, the ROI will mainly cover the epicardium and cannot effectively respond to the contraction of the myocardium. If the apex is too low, it will not be able to effectively cover the myocardium. All of these may lead to inaccurate RLS values. Also, when manually modifying the ROI, it should be noted that the ROI trajectory needs to avoid the papillary muscles. It should also be noted when defining the width of the ROI that if the width is too narrow, the tracking value results will be lower due to the lack of tissue data in the ROI. If the width of the ROI is too wide, the coverage area is too large, resulting in the tracking result being lower than the actual value or the collected segmental image being missing (12). Attention should be paid to adjusting according to patients with cardiac hypertrophy so that the width of the ROI is consistent with the hypertrophic myocardium.

Influence of aortic valve closure time adjustment

First and foremost, the clear display of the aortic valve is a prerequisite. On this basis, the left ventricle must be clearly displayed throughout the cardiac cycle. That is, in the end-systole frame, the entire left ventricle needs to be displayed, whereas in the end-diastolic frame, the annulus is not shown. After obtaining a good standard left ventricular section, the appropriate AVC time should be selected in order to get accurate diagnosis (13). Aortic valve closure timing adjustment is an important step in defining end-systolic strain parameters. Its information has important implications for the accuracy of the AFI results. Normal aortic valve closure time includes the end of systole (ejection deceleration phase) and the entire diastolic phase. Accurate adjustment of the aortic valve closure time should be defined at the end of the T wave of the ECG. When the atrioventricular valve is open, the previous frame or when the intraventricular ventricle is the smallest, i.e., the first frame of the aortic valve being closed, it should be the exact accurate calculation time. The actual observation should be combined with electrocardiogram, atrioventricular valve and ventricular wall motion to further accurately determine the ventricular and valve movement phase (14). When the AVC time adjustment is more than one frame in advance, due to the relative enhancement of the ventricular movement in the fast ejection period, the results of the strain values of the AFI segments are high. When the AVC time adjustment lag is greater than one frame, the ventricular diastolic motion is weakened, and the results of the AFI strains in all segments are generally low. *Table 2* shows that the strain values of the apical, mid-segment, and basal segments of the ventricle are all lower than those of normal when the AVC timing is delayed. In the process of statistical analysis, we found that the GLS of the three-chamber view remains basically unchanged when the AVC timing adjustment changes, which shows the GLS consistency of the three-chamber view (15).

Influence of image frame rate selection

In the AFI inspection, the frame rate under normal circumstances should be between 40–80 frames/s. In the group of valid examiners, when the frame rate is lower than 40 frames/s, only the apex segments of the strain value difference were statistically significant, and the basis and mid segments of the strain value difference were not statistically significant. Frame rate is too low, which caused the decrease of image temporal resolution, resulting in the image cannot be clearly distinguished. High frame rate can capture subtle changes in motion information (16), and high-speed movement of the organ scanning is necessary. Heart is the body's high-speed movement of organs. Especially when the heart rate is high, it is recommended to use high frame rate. When the heart rate is greater than 120 beats/min, AFI is not recommended, since the frame rate cannot meet the AFI image capture standards, which will lead to inaccurate measurement results.

To sum up, transthoracic echocardiographic AFI does not apply to every clinical patient. In this study, the efficacy rate is about 74% (17). RLS results are affected by many factors in the operation, include of endocardial trajectory tracing (ROI), aortic valve closure time adjustment and image frame rate selection, we should pay attention to these factors, avoid them, and improve the accuracy of the results.

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None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: The study was approved by the ethics committee in Sichuan Integrative Medicine Hospital, Chengdu 610000, China. Written informed consent was obtained from the patient.

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