Effect of B-value in revealing postinfarct myocardial microstructural remodeling using MR diffusion tensor imaging

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1. Introduction

Magnetic resonance diffusion tensor imaging (DTI) has been regarded as a powerful tool to nondestructively characterize myocardial microstructure [1–5]. In normal hearts, left ventricular (LV) myocardial fiber orientation changes smoothly from left-handed in epicardium to right-handed in endocardium when viewed from apex [1–4], which is well validated with histological measurements [6–8]. This double-helical myocardial fiber architecture is essential for dispersing strain uniformly and conserving energy expenditure [9], and has been widely observed in humans [10] and other mammalian species [11]. Besides fiber orientation, other intrinsic myocardial characteristics, including fiber direction-

al integrity and water molecule mobility [12], can be represented by derived DTI indices, such as fractional anisotropy (FA), mean diffusivity (MD), and directional diffusivities along myofiber axial (λ∥) and radial (λ⊥) directions. Recently, these DTI indices together with fiber architecture have been extensively utilized to monitor microstructural alterations of hearts with myocardium infarction (MI) [13–19]. The double-helical structure was reported to be reorganized with shifting towards more left-hand orientation in both infarcted and non-infarcted myocardium [13–15,17] with increase of local angular dispersion compared to normal hearts [13,16]. As contribution of myofiber to cardiac contraction was heterogeneous across myocardial wall [20] and related with fiber orientation, alteration of the fiber architecture would subsequently impair heart function. During the acute phase of MI, decrease of MD and increase of FA were observed in the infarcted myocardium, indicating myocyte swelling and lengthening [16,21]. Gradually with infarct formation, MD was found to increase and FA decrease, reflecting the appearance of myocyte necrosis and fibrosis [13–17]. All these experimental and clinical studies have
demonstrated the powerful ability of DTI in probing myocardial remodeling process.

In recent years, in vivo cardiac DTI is becoming feasible for animal [22,23] and human [14,18,24] studies by alleviating motion artifacts with incorporating motion-compensation methods, such as ECG triggering, respiratory navigation, or breath-holding. Quantitative DTI index maps and 3D myocardial fiber tractography were successfully achieved in beating hearts, demonstrating the feasibility of the technique in description of in vivo heart microstructure. Such imaging approach provides a novel way for longitudinally tracing and evaluating the remodeling evolution of diseased hearts at microscopic level, which may benefit the development of specific therapeutic strategies.

It is noteworthy that most of the previous cardiac DTI studies assumed free water diffusion mode inside of myocardium, and the diffusion-weighted (DW) signal was of monoeponential dependence on the diffusion sensitivity of b-value, which therefore had no impact on DTI index quantification. However, nonmonoeponential diffusion decay at high diffusion strengths (>1000 s/mm²) has been observed in perfused rabbit [25] and rat [26] hearts, which uncovered the complicate diffusion behavior in myocardium and implied the possible effect of b-value on conventional DTI index characterization. Despite of this potential limitation, the conventional DTI method is still widely accepted as a fast, robust and reliable protocol to explore water diffusion characteristics in routine research and clinical settings. Especially, its ability in detecting microstructural alterations may be greatly strengthened with b-value optimization. Recently, b-value dependence of DTI measurement in monitoring biological tissue changes has been explored in normal developing brains [27] and some abdomen organs with ischemia reperfusion injury [28,29] in rat models. Quantifications and abilities of specific DTI indices in exploring tissue structural alterations were found to vary with b-values. These experimental results not only demonstrated the crucial role of b-value in DTI index measurement, but also confirmed the necessity of optimizing it for better detecting structural changes when using conventional DTI analysis. These important findings then prompt us to make the present endeavors to determine if such b-value dependence of DTI index characterization exists in ex vivo heart samples.

The current study was conducted on a rabbit model due to its advantages of intermediate body size, easy handling, favorable cost effectiveness and pertinent outcomes to human patients with similar cardiovascular conditions [30]. Fixed heart samples of normal and infarcted rabbits at 1, 3, 5, and 7 days after MI surgery underwent ex vivo DTI scans. B-value impact on DTI index quantification was explored, and optimal b-values to achieve the most sensitive and abilities of specific DTI indices in exploring tissue structural alterations were found to vary with b-values. These experimental results not only demonstrated the crucial role of b-value in DTI index measurement, but also confirmed the necessity of optimizing it for better detecting structural changes when using conventional DTI analysis. These important findings then prompt us to make the present endeavors to determine if such b-value dependence of DTI index characterization exists in ex vivo heart samples.

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2. Methods

2.1. Sample preparation

The animal experiments were approved by the local institutional ethics committee for animal research. Twenty-four adult New Zealand rabbits (≈2200 g, 12 males and 12 females) were anesthetized, and the proximal left circumflex (LCX) coronary artery was permanently occluded with a surgical suture to create MI approximately at lateral myocardial wall [31]. Animals were randomly classified into 4 groups, each of which was composed of equal male and female subjects to reduce the bias arising from potential gender influence [32,33]. Together with 6 intact controls with similar physiological conditions, the infarct groups were sacrificed at 1, 3, 5, 7 days after MI surgery with denoted as D1, D3, D5, and D7, respectively. The hearts were then arrested and fixed with formalin for one week to allow the possible early ventricular geometry changes [6] before ex vivo MRL. Heart sample preparation and MR experiment were both performed at a room temperature (≈20 °C).

2.2. MR experiments

The imaging experiments were conducted on a whole body 3T Siemens MAGNETOM TIM Trio scanner (Siemens Medical Systems, Erlangen, Germany). A two-channel radio-frequency coil with 5 cm diameter and 9 cm length was custom-built. The heart sample was immersed in formalin to avoid tissue-air susceptibility artifact, and held in a needle-removed syringe. The syringe was then placed inside of the coil with the sample located at the coil center and the cardiac long axis parallel to the coil axis. A multi-shot readout-segmented echo-planar imaging diffusion tensor imaging (EPI-DTI) [34] was performed on LV short-axis planes with the following parameters: TR = 4000 ms; TE = 90 ms; FOV = 100 mm²; matrix size = 128 × 128; image resolution = 0.78 × 0.78 × 1.2 mm³; slice gap = 0.2 mm; number of readout segments per image = 7; echo-spacing = 0.5 ms; EPI factor = 64. The slices number was dependent on heart sample size and typically around 13, and number of average = 4. Nine nonzero b values from 500 to 2500 s/mm² with a step of 250 s/mm² were applied in 6 diffusion directions. The diffusion time was fixed over the measured b-value range, with diffusion gradient duration Δ = 27.34 ms and diffusion time δ = 45.32 ms. The total scan time was ≈2 hours per sample.

2.3. Data analysis

On each short-axis slice, the intersection of the inter-ventricular septum with the right ventricle was manually identified, and the remaining LV wall was equally divided into three segments as anterior, lateral, and inferior [13]. Infarcted myocardium was recognized as hyperintense in DWI with b value of 0, typically exhibiting thin myocardial wall. In infarct group, the segment where infarction largely located was identified as infarct region, of which the bilateral segments were adjacent regions, and the remaining part was remote region. For control group, lateral wall was arbitrarily regarded as sham infarct region with sham adjacent and sham remote regions subsequently defined (Fig. 1).

Noise level was calculated as the averaged amplitude of background noise at four corners of each slice. Data points were only included in the analysis if their signal intensities for the entire range of applied b-values were three times greater than the background noise level [35]. To further increase signal-to-noise ratio (SNR) for facilitating reliable DTI index quantification, the signal of each voxel on LV myocardium was averaged with its four adjacent voxels within the same slice [36]. With such retrospective

![Fig. 1. Definition of infarct, adjacent and remote regions in the (A) infarcted, and (B) control heart samples.](image-url)
way to enhance SNR, the actual spatial resolution was dependent on neighboring pixel number involved for average and may be flexibly adjusted based on SNR requirement. Single tensor measurements were performed from the DWIs with two b-values, namely 0 versus 500, 750, 1000, 1250, 1500, 1750, 2000, 2250, or 2500 s/mm² respectively using the conventional DTI analysis model of $\frac{DW(b)}{DW(0)} = \exp(-bD)$, from which the primary eigenvector and the three eigenvalues were calculated. Then, DTI indices, including FA, MD, $\lambda_\parallel$, and $\lambda_\perp$, at each specific b-value were computed pixel-by-pixel on each slice. These DTI index maps were also computed by fitting all DWIs with all ten (1 zero and 9 non-zero) b-values to the aforementioned diffusion monoexponential (ME) model. In each sample, DTI indices were averaged among 6 representative slices with MI in infarct, adjacent, and remote regions, respectively.

One-way analysis of variance (ANOVA) with post hoc Bonferroni’s multiple comparison tests were performed to assess the effect of b-value on DTI index ability in monitoring myocardial microstructural changes with $p < 0.05$ regarded as significance. For each b-value, the detection ability of DTI index was evaluated by the total number of statistical significances [27] among infarct and control groups. Unless otherwise stated, all data are presented as means ± standard deviation (SD).

3. Results

Maps of FA, color-coded FA, $\lambda_\parallel$, and $\lambda_\perp$ computed from DW images using different two b-value sets (i.e., 0 versus 5 representative non-zero b-values of 500, 1000, 1500, 2000, and 2500 s/mm²) as well as using all ten b-values via ME fitting were illustrated in Fig. 2. Each type of DTI index maps was displayed in the same grayscale for all groups. Myocardial fiber orientation, with red-green-blue colors representing the directions of left-right, up-down, and in-out, respectively, were observed to be mostly preserved at all b-values in all groups. As MD was linearly correlated with $\lambda_\parallel$ and $\lambda_\perp$, it should show the similar alteration trend with the two directional diffusivities (not shown).

Fig. 3A shows the normalized diffusion signal intensity of entire LV myocardium on a representative short-axis slice before averaging the signals with adjacent voxels to increase SNR. The signal amplitudes were found to be apparently greater than those of background noise at all b-values, ensuring limited noise influence on DTI index characterization. Variation of DW signals in control and D5 with b-values was illustrated in Fig. 3B. Ideal monoexponential decay curves were also obtained by fitting the DW signals at relatively small b-values (0 to 1000 s/mm²) to the monoexponential

![Fig. 2. Maps of (A) FA, (B) color-coded FA, (C) $\lambda_\parallel$, and (D) $\lambda_\perp$ computed from DWIs using different two b-value sets (i.e., 0 versus 5 representative non-zero b-values of 500, 1000, 1500, 2000, and 2500 s/mm²) as well as using all ten b-values via monoexponential fitting (ME) in infarct and control groups. Note that each type of DTI index maps was displayed in the same grayscale for all groups. The unit of diffusivity is $\times 10^{-3}$ mm²/s.](image-url)
In both control and D5, the DW signals exhibited apparent deviation from the fitted monoexponential decays at larger b-values (>1000 s/mm²), which was also observed in the other infarct groups (not shown), confirming the nonmonoexponential diffusion behavior in both infarcted and normal heart samples.

In infarct region, values of $\lambda_||$, $\lambda_\perp$, and MD calculated from different nonzero b-values were illustrated in Fig. 4. All the DTI indices were found to gradually decrease with b-values. The numbers of statistically significant differences detected by FA were found to be almost identical at all b-values but slightly decreased at the lowest b-value. Note that the difference became the most pronounced at moderate b-values of 1500 to 2000 s/mm² where all inter-group p-values were smaller than 0.01. Compared to controls, significant reduction of FA in infarcts was exhibited, and especially D3 was substantially lower than the other infarcts. Meanwhile, the abilities of $\lambda_||$, $\lambda_\perp$, and MD in reflecting diffusivity alterations were observed to decrease at both low and high b-values, and statistical differences of post hoc inter-group comparisons were the most significant at relatively small b-values (750 to 1500 s/mm²). Specifically, $\lambda_\perp$ of D3 and D5 increased conspicuously compared to that of D7, and D3 was also found to be statistically greater than control. In addition, D3 showed apparently higher $\lambda_\perp$ than the other groups, and $\lambda_\perp$ in D5 was significantly greater than controls. With the concurrent contribution of $\lambda_\parallel$ and $\lambda_\perp$, prominent increment of MD in D3 was shown compared to those of control, D1, and D7, while D5 exhibited substantially larger MD than controls. Note that the DTI indices and their ability in reflecting myocardial microstructural alterations computed from all ten b-values via ME fitting usually fell within those at the lowest and highest b-values. Generally, optimal b-values for sensitive detection of microstructural changes obtained from all ten b-values by ME fitting largely fell within those at the lowest and highest b-values. These results demonstrated that b-values affected the ability of DTI indices to reveal tissue changes. Typically, alterations of FA and diffusivities in adjacent region could be efficiently detected with using moderate and relatively small b-values, respectively.

Fig. 5 shows variations of DTI indices with b-values in adjacent region, which were found to be largely similar with those observed in infarct region. As for FA, the number of statistical significances reduced at both small and large b-values, and the greatest ability of FA to monitor change of diffusion anisotropy appeared at moderate b-values of 1500 to 1750 s/mm². All infarcts exhibited severe deterioration of fiber integrity compared to controls, and FA in D3 was significantly lower than those of D1 and D5. Meanwhile, abilities of both directional and mean diffusivities to disclose alteration of diffusion rate were shown to weaken with b-values. Specifically, D3 exhibited significantly greater $\lambda_\parallel$ than that of D7 only at small b-values no greater than 1000 s/mm². Similarly, substantially higher $\lambda_\perp$ in D3 compared to those of control, D1, and D7 could be efficiently detected at b-values lower than 1500 s/mm², beyond which some differences tended to be indistinguishable. Concomitantly, the strongest ability of MD to detect microstructural deterioration presented at a rather small b-value of 500 s/mm², when significant increase of MD in D3 compared to those of control, D1, and D7 could be effectively monitored. With increment of b-value, however, the significant difference of MD between D3 and control/D1 was difficult to be found. The DTI indices and their ability in monitoring myocardial microstructural changes obtained from all ten b-values by ME fitting largely fell within those at the lowest and highest b-values. These results demonstrated that b-values affected the ability of DTI indices to reveal tissue changes. Typically, alterations of FA and diffusivities in adjacent region could be efficiently detected with using moderate and relatively small b-values, respectively.

4. Discussion

"Slow" and "fast" diffusion pools were reported to coexist in complex biological tissues. Specifically, the slow diffusion pool comprises water that interacts by electrostatic forces with the proteins, cytoskeleton, and membranes of the cell, and the fast one consists of the remaining water in the intracellular or extracellular space [37]. It was generally accepted that small b-values tended to reveal information of fast diffusion pool, and large b-values helped slow diffusion to dominate the overall diffusion [38]. Therefore, an appropriate b-value would benefit DTI to better reveal structural change of infarcted myocardium with emphasizing
the predominantly altered diffusion part and consequently strengthen the ability of conventional DTI analysis in detecting remodeling process of diseased heart, which was exactly the main motivation of the current study.

During the approximately first week after MI, the infarcted myocardium was reported to undergo necrotic and fibrosis phases, respectively [39]. Infarct rupture was most common at the necrotic phase [40], which presumably began within a few hours after MI and

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**Fig. 4.** Quantification and ability of (A) FA, (B) axial diffusivity (\( \lambda_\parallel \)), (C) radial diffusivity (\( \lambda_\perp \)), and (D) MD in detecting alteration of myocardial microstructure in infarct region at different b-values as well as monoexponential fitting (ME) using all ten b-values. The differences of the DTI indices among infarct and control groups were evaluated using one-way ANOVA followed by post hoc Bonferroni’s multiple comparison tests. The total number of statistically significant differences at each b-value is indicated above the column with number of p-value smaller than 0.01 shown in parentheses. *p < 0.05, *p < 0.01. The unit of diffusivity is \( \times 10^{-3} \text{ mm}^2/\text{s} \).
ended at ≈5 to 7 days. Wavy fibers of infarcts were exhibited arising from apparently extracellular edema [41], resulting in increment of overall diffusion. Simultaneously, the infarcted muscles lost their striations with altered staining properties. Significant decrease of collagen fibers and collagen struts laterally connecting myocytes was observed [42]. This progressive damage to the collagen networks led

Fig. 5. Quantification and ability of (A) FA, (B) axial diffusivity ($\lambda_a$), (C) radial diffusivity ($\lambda_r$), and (D) MD in detecting alteration of myocardial microstructure in adjacent region at different b-values as well as monoexponential fitting (ME) using all ten b-values. The differences of the DTI indices among infarct and control groups were evaluated using one-way ANOVA followed by post hoc Bonferroni’s multiple comparison tests. The total number of statistically significant differences at each b-value is indicated above the column with number of $p$-value smaller than 0.01 shown in parentheses. $^* p < 0.05$, $^* p < 0.01$. The unit of diffusivity is $\times 10^{-3}$ mm$^2$/s.
myocardial structure to be less organized and less anisotropic. Subsequently, the healing infarct entered the fibrotic phase (probably starting at $\approx 5$ to 7 days after MI and lasting $\approx 1$ to 2 weeks), where new collagen deposition dominated the structural and mechanical changes [39]. The healing infarct was composed of a mixture of collagen types I, III, and other minor subtypes [43]. The type III collagen served as the scaffold for subsequent deposition of the highly aligned type I collagen fibers [44] in a pattern similar to

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**Fig. 6.** Quantification and ability of (A) FA, (B) axial diffusivity ($\lambda_\parallel$), (C) radial diffusivity ($\lambda_\perp$), and (D) MD in detecting alteration of myocardial microstructure in remote region at different b-values as well as monoexponential fitting (ME) using all ten b-values. All the DTI indices were found to gradually decrease with b-values as observed in infarct and adjacent regions. No statistically substantial difference was found among infarct and control groups. The unit of diffusivity is $\times 10^{-3}$ mm$^2$/s.
that of normal muscle fibers [45]. Consequently, myocardial fiber directional coherence was improved and diffusion extent of myocardium was lessened with formation of collagen fibers. In brief, myocardial microstructural degradation and recovery during the first 7 days after MI largely involved changes of interstitial space, myocyte properties, organization of collagen fibers and struts, and so on, which may be originated from different microscopic levels with dissimilar diffusion environments.

In the current study, the optimal b-values were determined as those with the greatest total number of statistical significances among infarct and control groups. The findings were based on DTI experimental observations rather than strictly mathematical deduction nor by designing optimal diffusion gradient schemes [53], which however might be included in future studies to improve estimation performance.

4.1. B-value dependence of FA quantification and ability in detecting myocardium changes

FA quantification was found to be influenced by b-value as observed in previous studies [27], which may be related with the complex anisotropic microstructures [46] that made the measurement dependent on microstructural orientation [27]. As aforementioned, FA alteration during the first week of MI mainly arose from change of myocyte, collagen fibers and struts. On one hand, the occurrence of altered collagen fibers and their struts would lead to reorganization of intracellular and extracellular structures, which were typically classified into the fast diffusing pool. On the other hand, myocyte showed clear change of staining properties and collagen fibers during the first week of MI mainly involved changes of interstitial space, which was reported to belong to the fast diffusion pool [37]. Consequently, myocardial structural alterations computed from all ten b-values via ME fitting or other more complex diffusion models, such as biexponential model, has to involve DTI data acquired at multiple b-values, which would inevitably lengthen scan time and may not be preferred in clinical practices.

4.2. B-value dependence of diffusivity quantification and ability in detecting myocardium changes

Recently, neurite beading was proposed as a novel biophysical model to describe the pathological mechanism of cell swelling occurred in ischemic brains [47]. Both DWI simulated and experimental results demonstrated that the decrease of intracellular diffusion was mainly responsible for the observed drop of overall MD after ischemic injury. However, at necrotic and fibrosis phases, the infarcted hearts exhibited increase of MD compared to controls, which was found to be related with increase of $\lambda_\parallel$ and $\lambda_\perp$ arising from apparently extracellular edema [41] and myocyte lengthening during the process of eccentric hypertrophy [16], respectively.

Mean and directional diffusivities, represented by MD, $\lambda_\parallel$, and $\lambda_\perp$, were generally found to decrease progressively with diffusion strength. With increment of b-value, slow diffusing component was prone to be emphasized, leading to gradual decrease of apparent diffusivities as observed in this study. In both infarct and adjacent regions, b-value was found to substantially affect the abilities of mean and directional diffusivities in detecting myocardial microstructural alterations. Extracellular edema during the necrotic phase and formation of collagen fibers during the fibrotic phase respectively resulted in augmentation and decrement of extracellular space, which was reported to belong to the fast diffusion pool [37]. Thus, relatively small b-values would help to detect alterations of these microstructures. In the current study, the greatest abilities of diffusivities were usually attained at relatively small b-values no larger than 1500 s/mm$^2$, consistent well with the expectation above.

DTI indices and their ability in reflecting myocardial microstructural alterations computed from all ten b-values via ME fitting generally fell within those at the lowest and highest b-values. Note that such ME fitting or other more complex diffusion models, such as biexponential model, has to involve DTI data acquired at multiple b-values, which would inevitably lengthen scan time and may not be preferred in clinical practices.

Fig. 7. Masson's trichrome-stained views of representative myocardial tissues in the infarct, adjacent, and remote regions of each group. Compared to the controls, the infarcted myocardium exhibited apparent degradation of fiber integrity/directional coherence and alteration of extracellular space. Substantial fiber tearing was clearly seen in the adjacent regions, but not in the remote regions.
4.3. Evaluation of noise influence

Some DTI indices, such as FA, were known to be sensitive to detrimental effects of noise, and would be misestimated with noise contamination [48]. In the current study, data points were only included in the analysis if their signal amplitudes for the entire range of applied b-values were three times greater than the background noise level [35], alleviating noise influence on DTI index evaluation. In addition, the signal intensity of each voxel on LV myocardium was averaged with its four adjacent voxels within the same slice [36] to further enhance SNR. It was reported that SNR-related diffusion anisotropy variation could be efficiently reduced when the SNR of DWIs was greater than 20 [49]. In the current study, the averaged SNRs of DWIs were typically 24 for the largest b-value of 2500 s/\text{mm}^2 and 89 for the smallest b-value of 500 s/\text{mm}^2, which guaranteed reliable DTI index measurement owing to very low noise-to-signal ratio (<0.05) [50].

In this study, the single tensor model predicting error arising from noise was also assessed by evaluating FA value in the surrounding isotropic medium [51,52] (i.e., formalin) with ROI size of ≈200 pixels. The averaged FA values of all groups were 0.04 ± 0.01, 0.04 ± 0.01, 0.03 ± 0.01, 0.03 ± 0.00, 0.03 ± 0.00, 0.04 ± 0.00, 0.04 ± 0.00, 0.04 ± 0.00, 0.05 ± 0.00 and 0.02 ± 0.00 at non-zero b-values of 500, 750, 1000, 1250, 1500, 1750, 2000, 2250, 2500 s/\text{mm}^2 as well as ME fitting using all b-values, respectively. The non-zero FA value in formalin was hypothesized to be related with the single tensor model predicting error, although it may be also partly contributed from impurities suspending in formalin. These FA values were found to be similar among all b-values, indicating similar single tensor model predicting error at all b-values. Therefore, the predicting error should have little influence on the obtained results of current study.

4.4. Limitations of the current study

There were several limitations in the current study. First, two other infarct phases during cardiac remodeling process, namely the acute ischemia phase (lasting several hours immediately after MI) and remodeling phase (following the fibrotic phase) [39], were not included in the current study. At the acute ischemia phase, the infarcted myocardium was found to exhibit neither apparent hyperintense in DWI with b-value of 0 nor thin myocardial wall with the current resolution, making segmentation of myocardium for analysis difficult. Therefore, this infarct phase was not included in this study. In addition, the rabbits would be hard to survive for several weeks with MI, leading acquisition of DTI data at the remodeling phase to be rather unstable. As the infarct mechanics at these two phases may be different with the explored necrotic and fibrotic phases, the respective optimal b-values may not be fully consistent with the attained ranges in this study. In future study, high-field animal MRI scanner may be needed for better identification of the acute infarcted myocardium, and animals easier surviving with MI may be employed for reliable optimization of b-values at remodeling phase. Second, the current study was performed on excised nonperfused heart samples, on which the impact of vascular perfusion could be negligible. However, this kind of contribution has to be considered in perfused or in vivo hearts with apparent fluid/blood flow, making current findings not directly apply. Intravoxel incoherent motion model [54] (i.e., biexponential model) may be helpful for separation of perfusion contributed from flow and diffusion existing in myocardium. B-value optimization would be more complicated with simultaneous considerations of sensitively monitoring myocardial microstructural alterations as well as efficiently differentiating perfusion and diffusion components. This work might be conducted in the future. Nevertheless, the current study demonstrated the important impact of b-value in detecting heart microstructural remodeling. The experimental results may provide useful information for DTI protocol parameter optimization in investigating hearts at other pathological or in vivo states. Third, temperature and formalin fixation can alter water diffusion properties and affect the actual FA and ADC values. In the current study, all samples were fixed for one week and kept in the similar temperature (≈20°C) during the experiment, which guaranteed the same impact of temperature and dehydration on each heart. Note that although the absolute DTI indices may vary with temperature and fixation duration, their alteration trend with b-values and the optimal b-value range to detect postinfarct microstructural changes may likely remain similar with the current findings. Fourth, average of the diffusion signal with neighboring pixels or within the infarct region would affect the measured DTI indices of infarcted myocardium if any non-infarcted myocardium included, and the degree of postinfarct alterations would be underestimated to some extent. In the current study, predominance of infarction in infarct region was generally observed, especially for hearts with MI 3 days or more (Fig. 2), ensuring the current findings of postinfarct microstructural changes to be true.

5. Conclusion

Nonmonoexponential diffusion behavior in myocardium was confirmed. DTI indices were observed to decrease gradually with b-values in all regions and groups. Optimal b-value range for sensitive detection of microstructural alteration varied with targeted DTI indices. Specifically, FA showed the most sensitive detection of fiber integrity degradation at moderate b-values (≈1500 to 2000 s/\text{mm}^2), and the strongest ability of mean and directional diffusivities in monitoring diffusivity alteration occurred at relatively small b-values (≤1500 s/\text{mm}^2) during the necrotic and fibrotic phases. The experimental results not only demonstrated b-value dependence of DTI index quantification, but also indicated that an optimal b-value can strengthen the DTI ability to sensitively monitor myocardial remodeling with conventional DTI analysis. These findings may provide useful information for DTI protocol parameter optimization in assessment of heart microstructures at other pathological or in vivo states in the future.

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