A morpho-biomechanical model at the interface between infarcted and non-infarcted myocardium via multiscale bioimaging

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Background: Healing after myocardial infarction is based on the formation of a fibrotic scar resulting in a heterogeneous heart muscle contraction. The prediction of morpho-biomechanical characteristics on remodelling of various regions of heart such as remote, scar, and border following myocardial infarction cannot fully be comprehended until now. The mechanical turnover of the heart performance is primarily based on the morphologycal and biomechanical remodeling of various heart regions. The recovery of heart performance, depends on the morpho-biomechanical characteristics at the border zone as the survived cells limit the injuried area.

Aim: To which extend the morpho-biomechanics of border zone sustain and monitor the restoring function of heart within the healing period of 28 days was the triggered question of this study.

Methods: Heart mouse tissues were sampled at different post- myocardial infarction periods (1 day, 4 days, 7 days, 14 days, 21 days, 28 days). The morphological characteristics of border zone were investigated by liquid-atomic force microscopy, while Derjagin, Muller, Toropov model (DMT) was used to quantify the Young's modulus (*E*).

Results and Discussions: Two distinct morphological signatures developed at the border zone: in remote area collagen fibers follow the compact alignament of cardiomyocytes, while dense fine network structures filled the interstitial space between cardiomyocytes. In scar, dense myofibrils aligned predominantly anisotropically. Large voids are present in the scar area, which further extends into the remote area. The two distinct morphological patterns of scar and remote areas seem to follow the progressive accumulation of collagen at border. A higher amount of collagen is estimated at 1 day post-MI (37.8 ± 8.5%) at the border zone than that of control (0.3 ± 0.1%). After 7 days post-MI, the increase collagen amount levels at a value of 54.7 ± 11.45%. As a fact, higher collagen accumulation and its anisotropy conducted to different biomechanical signatures of remote and scar. While both scar and remote areas are less compliant at 7 days post-MI (E_{remote}= 27.3 ± 5.8 MPa, E_{scar} = 30.5 ± 3.1 MPa), after 28 days post-MI remote and scar areas recover their compliance (10.5 ± 3.0 MPa) and approaches that of $E_{control}$ = 6.8 ± 2.7 MPa. The local concetrated stress developed in scar area seems to dissipate into less tension regions such as remote area till equilibrium tension is reached. Both scar and remote areas recover their compliance. We may hypothesize that a controlled accumulation and assembling of collagen at the border zone optimizes the heart biomechanics performance. The inadequate accumulation of collagen fibers with random broken links may uncontrollably assist the heart remodelling. At the maximum tension, large gaps between remote and scar areas may develop, thus leading to a progressive left ventricular dilation (LV). Consequently, the left ventricle thins, whereas the infarcted area may uncontrollably expand causing ultimately heart rupture.

Conclusions: Studies conducted at the border zone anticipated that the biomechanics is the key player in tissue heart remodelling. The regional biomechanical modifications in heart modulates the synthesis, distribution and architecture of collagen and may predict the heart survival or rupture.