Title
State of energy of ventricular flow: A cause or the first indicator of adverse remodeling?

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State of energy of ventricular flow: A cause or the first indicator of adverse remodeling?

Ventricular remodeling is characterized as a set of molecular, cellular, and interstitial changes that occur in the heart in response to a disease or insult, which clinically manifest as changes in size, mass, anatomy, and function of the heart. Overall remodeling is the culmination of a multifaceted series of transcriptional, signaling, structural, electrophysiological, and functional events occurring within the cardiac tissue. These proceedings could result in short-term benefit, but like any inflammatory processes if they remain persistent, they turn into mal-adaptive or adverse remodeling, and predispose to cardiovascular morbidity and mortality. Ventricular remodeling often begins as minor degradations of the heart function, which may be difficult to detect, then progressively develops, and eventually leads to full manifestations of heart failure [1]. Identifying the primary changes that triggers the sequence of events leading to remodeling is of paramount importance to establish physics-based predictive models in cardiology.

In recent years, numerous studies have highlighted the significance of ventricular blood flow dynamics to gain a deeper understanding of cardiac function [2]. Indeed, ventricular contraction’s ultimate purpose is to generate and sustain pulsatile blood flow while avoid overpressure and turbulence. These phenomena mechanistically involve an interplay between kinetic energy (KE, proportional to the square of blood velocity), potential energy (proportional to pressure gradients) and work performed by the myocardium. This sequence of events is achieved through the reciprocal forces exchanged between blood and surrounding tissues. To make the picture more complex, intraventricular pulsatile blood flow forms vortices, peculiar flow features that can either preserve kinetic energy into a rotatory movement or dissipate kinetic energy by incoherent flow structures (turbulence).

The delicate process of remodeling can lead to perturbations in the ventricular blood flow. Nature optimizes the ventricular blood flow momentum and energy transfer through the heart via propulsion and vortex formation; any changes in the composition and function of the heart may lead to deviation of optimal flow energetics and momentum transfer within the heart [8]. In healthy hearts, the transmitral vortex helps effective transfer of the blood flow momentum and energy and minimizes the stroke work [9]. If adverse remodeling affects any of the above, diastolic vortex flow is disturbed, which can drastically dissipate flow kinetic energy across the right or left heart. Changes in left or right ventricular structure and function affecting diastolic vortex formation ultimately would lead to higher or lower ventricular total energy, where a higher percentage of it is dissipated due to the formation of small incoherent flow structures (turbulence).

Changes in ventricular pressure due to remodeling is directly associated with an imbalance in the ventricular state of energy. This include ventricular flow kinetic energy and myocardial work, defined as the product of pressure and volumetric change. The state of energy reflects the delicate process of remodeling can lead to perturbations in the ventricular blood flow. Nature optimizes the ventricular blood flow momentum and energy transfer through the heart via propulsion and vortex formation; any changes in the composition and function of the heart may lead to deviation of optimal flow energetics and momentum transfer within the heart [8]. In healthy hearts, the transmitral vortex helps effective transfer of the blood flow momentum and energy and minimizes the stroke work [9]. If adverse remodeling affects any of the above, diastolic vortex flow is disturbed, which can drastically dissipate flow kinetic energy across the right or left heart. Changes in left or right ventricular structure and function affecting diastolic vortex formation ultimately would lead to higher or lower ventricular total energy, where a higher percentage of it is dissipated due to the formation of small incoherent flow structures (turbulence).

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one or more of such aspects, ventricular compensation develops, which often leads to a vicious cycle where ventricular dilatation and loss of contractility negatively affect the ventricular state of energy and ultimately progresses toward adverse remodeling. Identifying early changes in heart function that are associated with the events leading to remodeling is still an unresolved challenge.

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References


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