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**Title**: Evolving imaging techniques for the assessment of cardiac structure and function and their potential clinical applications

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# SUMMARY AND CONCLUSION

The general introduction of the theses introduces the new imaging techniques for evaluation of tissue motion, myocardial deformation, and non-invasive assessment of electromechanical properties of the heart. Basic principles of these new techniques including tissue Doppler imaging and 2-dimensional speckle tracking imaging are described, and their potential incremental value in the clinical settings is summarized. In addition, advances in 3-dimensional imaging technology are discussed including their important role in promoting further development of new percutaneous therapeutic approaches for the valve disease. Finally, the objectives and the outline of the thesis are provided.

**Part I**

The first part of the thesis focuses on the evaluation of myocardial mechanics and their changes with treatment in cardiac diseases using novel echocardiographic techniques, including myocardial deformation imaging and color-coded tissue Doppler imaging.

The main focus of **Chapter 1** is the assessment left ventricular deformation parameters by 2-dimensional speckle tracking imaging in patients with coronary artery disease, and their prognostic value for prediction of clinical outcome. In acute ischemia, diastolic dysfunction often precedes the onset of systolic dysfunction. New global and load independent indexes of left ventricular diastolic function derived from longitudinal strain and strain rate analysis provided incremental prognostic information over that of left ventricular ejection fraction, thus allowing for early identification of high risk patients with acute myocardial infarction and not only decreased but, more importantly, preserved left ventricular systolic function.

Altered propagation of the electrical cardiac activity is the main determinant of abnormal left ventricular mechanics in a failing heart, resulting in asynchronous cardiac motion and impaired left ventricular twist. Restoration of left ventricular synchronicity has been associated with improved myocardial function in heart failure patients with favorable response to cardiac resynchronization therapy. Synchronization of systolic contraction explains in part the benefit derived from cardiac resynchronization therapy. However, diastolic dyssynchrony was shown to be more prevalent than systolic dyssynchrony (51.9% versus 46.2%) in heart failure patients with wide QRS complex **(Chapter 2)**. In addition, concomitant systolic and diastolic dyssynchrony was present in only 28.6% patients suggesting that the underlying pathophysiology of the two conditions may differ. Interestingly, both systolic and diastolic dyssynchrony significantly improved in the responders to cardiac resynchronization therapy. This suggests that biventricular pacing results not only in systolic resynchronization, but also in more synchronous relaxation pattern possibly due to reduced diastolic ventricular interaction, that may ultimately lead to improved left ventricular filling. This hypothesis was confirmed in **Chapter 3**, where cardiac resynchronization therapy exerted a beneficial effect on the left ventricular diastolic performance in the responders and in those with non-ischemic heart failure. Finally, **Chapter 4** reviews the effect of cardiac resynchronization therapy on novel echocardiographic measures of left ventricular performance. Assessment of left ventricular torsion in patients with heart failure who receive cardiac resynchronization therapy may help us to understand the pathophysiological mechanisms of response to this heart failure therapy.

**Part II**

Over the last few decades, significant advances in ultrasound, electronic and computer technology have enabled real-time volumetric imaging of the complex cardiac anatomy. Evolving clinical applications of 3-dimensional echocardiography and its integration with other non-invasive imaging techniques are discussed, with mitral valve assessment being the focus in **Part IIA**.

**Chapter 5** summarizes the evidence for advanced clinical applications of 3-dimensional echocardiography**,** including its usefulness for cardiac chamber volume assessments, left ventricular dyssynchrony assessments, quantification of valvular abnormalities, and its role during cardiac interventions. Mitral valve in particular has a complex saddle-shaped configuration and its assessment by 2-dimensional echocardiography may be challenging. Increasingly used minimally invasive surgeries or percutaneous valve repair techniques rely on accurate assessment of valve anatomy. Recently developed mitral valve quantification software has been demonstrated to be clinically feasible for the comprehensive assessment of mitral valve geometry with 3-dimensional echocardiography that is comparable to the multidetector row computer tomography measurements **(Chapter 6)**. In addition, the ability of 3-dimensional echocardiography to directly image vena contracta area allows accurate quantification of mitral regurgitation as compared to magnetic resonance imaging, with less underestimation of the regurgitant volumes than those measured by 2-dimensional echocardiography (1.2% and 21.3%, respectively, compared to magnetic resonance imaging), in particular in the patients with eccentric regurgitant jets **(Chapter 7)**.

Role of multimodality imaging in transcatheter aortic valve implantation is discussed in **Part IIB.** Integration of 2-dimensional and 3-dimensional echocardiography, computed tomography and magnetic resonance imaging in the assessment before, during and after the procedure may help to minimize procedural complications, and provide valuable data for the design of new devices **(Chapter 8)**. For example, accurate aortic root measurements, evaluation of spatial relationships with coronary ostia, and extent of valvular calcification are crucial for assessment of suitability for transcatheter aortic valve implantation and selection of appropriate prosthesis size. Novel automated multi-detector row computed tomography imaging post processing software results in faster measurements while maintaining the highest accuracy and reproducibility compared with manual techniques, which may allow standardization of measurements and promote procedural success rate **(Chapter 9)**. It also provides information on the most appropriate angiographic projection therefore potentially reducing the fluoroscopy and procedure time. Before transcatheter aortic valve implantation, direct measurements of often ellipsoid cross-sectional aortic annular and left ventricular outflow tract areas by 3-dimensional echocardiography and multi-detector row computed tomography may enable more accurate calculations of stroke volumes **(Chapter 10).**

**Conclusion**

Recently developed techniques for quantification of tissue motion and deformation including tissue Doppler imaging and 2-dimensional speckle tracking imaging have fundamentally altered the way echocardiography approaches the characterization of global and regional myocardial function. Evaluation of myocardial tissue mechanics by the novel imaging techniques provides information on the cardiac function that is incremental to that obtained by the conventional echocardiographic parameters. In particular, myocardial deformation imaging allows differentiations between active and passive myocardial contraction, thus may yield a more accurate assessment of myocardial viability and extent of myocardial scar. Moreover, multidirectional components of myocardial deformation enable detection of early myocardial dysfunction in patients with preserved left ventricular ejection fraction that are likely to progress into either systolic or diastolic heart failure. Direct assessment of myocardial relaxation may provide incremental information on left ventricular diastolic function that is less load dependent compared to the conventional Doppler derived parameters. Noninvasive assessment of the electromechanical properties of the heart by the new imaging techniques may help to enhance our understanding of the pathophysiology of heart failure and monitor the effect of therapy. Finally, 3-dimensional echocardiography is getting closer to routine clinical use. Together with multi-detector row computer tomography and magnetic resonance imaging, 3-dimensional echocardiography may become an integral part of cardiac multimodality imaging, with the goal to provide accurate data that lead to favorable outcomes and improved quality of life.