Surgeons have contributed studies of the pathophysiology and treatment of arrhythmias in experimental animals and patients during thoracotomy. This research has involved epicardial and endocardial pacemakers and implantable cardioverter-defibrillators (ICDs). Surgeons helped to define the mechanisms and ablation methods for supraventricular arrhythmias (including Wolff-Parkinson-White syndrome) and for ventricular tachycardia associated with post-infarction, ventricular aneurysms, and other conditions. In congenital heart disease, techniques for mapping the conduction system were developed by surgeons and used to avoid heart block during surgical repair. Therapies for atrial fibrillation developed in the operating room include atroventricular node ablation or modification and the Cox-maze operation. Mapping and ablation technologies developed by surgeons have evolved to standard methods used in the electrophysiology lab.

However, the development of resynchronization therapy for heart failure has largely bypassed the surgical arena. The epicardial approach has been marginalized as catheter technology has advanced and concern about the risks of general anesthesia and thoracotomy in patients with advanced heart failure has grown. However, arguably, the minimization of surgical contributions to resynchronization therapy has left important gaps in the understanding of how resynchronization therapy works, where it should be applied, and how it can be optimized. Following the early success of the Multicenter InSync Randomized Clinical Evaluation (MIRACLE) trial, implantation of biventricular pacemakers and pacemaker ICDs has expanded explosively. The worldwide market for resynchronization devices in 2007 is estimated to be in excess of 300,000 implants annually, at a market value of more than $7 billion for devices alone. However, with an incidence of non-responders of 25–30% (39% in the MIRACLE trial), roughly 90,000 of 300,000 recipients this year will not experience relief from symptoms of heart failure or functional benefit. While patients may benefit from defibrillation capabilities in these implants, the healthcare community will pay more than $2 billion for ineffective resynchronization therapy. Why does resynchronization therapy fail, and how can surgical investigators help?

Resynchronization therapy, developed for treatment of heart failure in dilated cardiomyopathy, partially reverses the effects of weakening and fibrosis of cardiac myocytes. Clinical manifestations of myocyte dysfunction include a left ventricular (LV) ejection fraction (EF) <35% and QRS interval above 120 milliseconds. Left bundle branch block is common in this syndrome. Segmental wall motion abnormalities and mitral regurgitation appear as heart failure progresses, reflecting the heterogeneity of electrical conduction velocity and contractile function. The hypothesis that simultaneous pacing of the septum and LV free wall could shorten the QRS complex, increase EF, restore synchrony, and improve symptoms was confirmed clinically. Resynchronization therapy has been associated with reduced mortality from heart failure in some settings. Resynchronization therapy also uniquely reduces myocardial oxygen consumption while improving function, an ideal combination previously characteristic only of mechanical assistance devices.

Most resynchronization therapy is performed with endocardial lead insertion under local anesthesia using a limited choice of ventricular pacing sites. Generally, the septum is paced with a conventional lead from the RV apex. The LV free wall is paced with a small cross-section lead from a ventricular branch of the coronary sinus. Inability to enter the os of the coronary sinus or to find an appropriate, stable location for coronary sinus pacing causes failure of implant procedures in 5–10% of candidates. Furthermore, the locations of coronary sinus branches, the tapering cross-section of those branches, and limitations of current technology reduce the number of usable pacing sites in any given patient. The ability to objectively compare small hemodynamic effects of pacing from different sites is limited by the time required to reposition the LV lead, optimally requiring multisite electrodes. Despite these difficulties, available data indicate that the location of the LV free wall lead is an important determinant of the efficacy of resynchronization therapy. Lateral and inferior LV lead locations have been utilized empirically. In dilated cardiomyopathy, it has been suggested that the LV lead should be
Factors determining the efficacy of resynchronization therapy include not only the location of the pacing leads but also the adjustment of timing parameters. The delay between stimulation of the right and left ventricles (optimal interventricular [VV] delay, interventricular delay [VVD], or ‘right–left delay’ [RLD]) are particularly important. Small changes in VVD can acutely increase cardiac output by 10% or more.23 Atrioventricular delay, heart rate, and interatrial delay may also affect optimization of resynchronization therapy. Given the multiple factors involved, it is remarkable that few randomized, objective comparisons of pacemaker settings have been reported, and that there is not even universal agreement about what optimization variables should be measured. Furthermore, it is not known whether pacing site and programming optimization are affected by changes in pre-load, afterload, and inotropic state. This knowledge gap is a potentially fertile ground for surgical investigators.

The role of the surgeon in resynchronization therapy includes back-up for failure of endocardial implantation. Implantation failed in an estimated 15–30,000 candidates in 2007 because of technical difficulty cannulating the coronary sinus or locating a useful free wall pacing site. However, most patients who fail coronary sinus lead insertion are not referred to thoracic surgeons for epicardial lead implants, yet recent studies indicate that surgical implantation of epicardial leads is safe, with good long-term results.24 Robotic approaches24 and minithoracotomy25 are available. With increasing experience, surgeons, anesthesiologists, and the industry can be expected to increase the safety and limit the discomfort of epicardial lead insertion. Minimal access approaches may ultimately allow epicardial leads to be inserted under local anesthesia. Moreover, the epicardial approach offers unique opportunities for definition of the pathophysiology of resynchronization. In contrast to limits faced by electrophysiologists, thoracotomy exposes the epicardial surface, providing the opportunity to seed electromagnetic or ultrasonic flow probes to accurately measure small changes in cardiac output during pacing optimization. Transesophageal and epicardial echocardiography are also readily applied in anesthetized patients. The use of anticoagulants for cardiopulmonary bypass further allows for the insertion of intracavitary pressure and/or conductance probes. When properly applied, these tools can provide important insight into the physiology and optimization of resynchronization therapy. Thus, surgeons can provide unique assistance to patients who fail conventional endocardial implantation. First, epicardial lead implantation may allow resynchronization therapy that is otherwise unavailable. Second, the surgical approach can optimize resynchronization therapy in ways that are not possible in the electrophysiology lab. This is likely to improve benefits in responders and might convert non-responders to responders. Finally, careful studies of ventricular mechanics may clarify why some patients fail to respond to biventricular pacing. This should improve methods of pacing and patient selection.

Our laboratory and other surgical investigators have described methods for optimizing resynchronization therapy, including the epicardial approach to randomized data collection and response surface visualization of results in humans.25 With a large number of patients currently undergoing resynchronization therapy and resources wasted in non-responders, clinical research is urgently needed. Resynchronization therapy is a promising technique, but its potential and limitations are incompletely understood. Surgeons can contribute to the evolution of this technology through clinical research in patients who fail conventional endocardial insertion or patients with advanced heart failure undergoing cardiac allografting. Potential benefits include not only improved results of epicardial lead insertion, but also optimized clinical benefit in responders and expansion of benefits to patients who fail to respond to resynchronization with current methods.

References