Biventricular Pacing/Cardiac Resynchronization Therapy (CRT)

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Overview

This Coverage Policy addresses the use of a biventricular pacemaker alone or combined with an implantable cardioverter defibrillator for cardiac resynchronization therapy (CRT), triple-site or triventricular pacing CRT, wireless pacing CRT, and His bundle pacing.

Coverage Policy

The use of a biventricular pacemaker alone or in combination with an implantable cardioverter defibrillator for cardiac resynchronization therapy (CRT) is considered medically necessary for ANY of the following indications when the individual has been on an optimal pharmacologic regimen before consideration of implantation:

- Ischemic cardiomyopathy, left ventricular ejection fraction (LVEF) \(\leq 30\%\), no prior implant, sinus rhythm (SR) for ANY of the following:
  - QRS 120-149 milliseconds (ms), left bundle branch block (LBBB), New York Heart Association (NYHA) Class I, II, III-IV
  - QRS \(\geq 150\) ms, LBBB, NYHA Class I, II, III-IV
  - QRS 120-149 ms, non-LBBB, NYHA Class III-IV
QRS ≥ 150 ms, non-LBBB, NYHA Class II, III-IV

- **Ischemic cardiomyopathy, LVEF 31-35%, no prior implant, SR for ANY of the following:**
  - QRS 120-149 ms, LBBB, NYHA Class I, II, III-IV
  - QRS ≥ 150 ms, LBBB, NYHA Class I, II, III-IV
  - QRS 120-149 ms, non-LBBB, NYHA Class III-IV
  - QRS ≥ 150 ms, non-LBBB, NYHA Class II, III-IV

- **Nonischemic cardiomyopathy, LVEF ≤ 30%, no prior implant, SR for ANY of the following:**
  - QRS 120-149 ms, LBBB, NYHA Class II, III-IV
  - QRS ≥ 150 ms, LBBB, NYHA Class I, II, III-IV
  - QRS 120-149 ms, non-LBBB, NYHA Class III-IV
  - QRS ≥ 150 ms, non-LBBB, NYHA Class I, II, III-IV

- **Nonischemic cardiomyopathy, LVEF 31-35%, no prior implant, SR for ANY of the following:**
  - QRS 120-149 ms, LBBB, NYHA Class I, II, III-IV
  - QRS ≥ 150 ms, LBBB, NYHA Class I, II, III-IV
  - QRS 120-149 ms, non-LBBB, NYHA Class III-IV
  - QRS ≥ 150 ms, non-LBBB, NYHA Class I, II, III-IV

- **LVEF > 35% of any etiology (ICD Indicated), no prior implant, SR, QRS ≥ 150 ms, LBBB, NYHA Class III-IV.**

- **LVEF ≤ 35% of any etiology (NYHA Class IV on Intravenous Inotropic Support), no prior implant for ANY of the following:**
  - QRS 120-149 ms, LBBB
  - QRS ≥ 150 ms, LBBB or non-LBBB.

- **Pre-Existing or anticipated right ventricular (RV) pacing with a clinical indication for ICD or pacemaker implantation, intrinsic narrow QRS, LVEF ≤ 35% when RV pacing anticipated is > 40%, NYHA Class I-II, III-IV.**

- **Pre-Existing or anticipated right ventricular (RV) pacing with a clinical indication for ICD or pacemaker implantation, intrinsic narrow QRS for ANY of the following:**
  - LVEF ≤ 35%, RV pacing anticipated ≤ 40%, NYHA Class III-IV
  - LVEF > 35%, RV pacing anticipated > 40%, NYHA Class I, II, III-IV

- **Refractory Class III/IV heart failure < 3 months post revascularization and/or ≤ 40 days post-myocardial infarction (MI), no other indication for ventricular pacing, LVEF ≤ 35% for ANY of the following:**
  - QRS 120-149 ms, LBBB or non-LBBB
  - QRS ≥ 150 ms, LBBB
  - QRS ≥ 150 ms, non-LBBB

The use of a biventricular pacemaker alone or combined with an implantable cardioverter defibrillator for CRT for any other indication is considered experimental, investigational or unproven.

Replacement of a biventricular pacemaker generator alone or in combination with an implantable cardioverter defibrillator and/or leads is considered medically necessary.
Triple-site or triventricular pacing CRT for any indication is considered experimental, investigational or unproven.

Wireless pacing CRT for any indication is considered experimental, investigational or unproven.

His bundle pacing (HBP) for any indication is considered experimental, investigational or unproven.

**General Background**

Congestive heart failure (CHF), or heart failure, is a clinical condition characterized by the heart’s inability to generate a cardiac output sufficient to meet the body’s circulatory demands. Approximately 20–30% of patients with heart failure may have intra-ventricular conduction delays, evidenced by a wide QRS interval on electrocardiogram (EKG), which can worsen left ventricular systolic dysfunction through asynchronous ventricular contraction. This abnormality appears to be associated with increased morbidity and mortality. The most frequently used index of cardiac function is the left ventricular ejection fraction (LVEF). Normal LVEF ranges from 50–75% at rest. Severe heart failure can reduce LVEF to < 35%. Treatment for heart failure includes: pharmacological therapy, which can include a combination of diuretics, digoxin, angiotensin-converting enzyme (ACE) inhibitors, angiotensin receptor blockers (ARB), beta-blockers and aldosterone antagonists. Some patients may remain symptomatic despite drug therapy. The definitive therapy for end-stage heart failure patients is heart transplantation.

Atrial fibrillation (AF) is the most common arrhythmia encountered in clinical practice, accounting for approximately one third of hospitalizations for cardiac rhythm disturbance. AF is prevalent in patients with CHF or valvular heart disease and increases in prevalence with the severity of these conditions. There are a number of AF treatment options. The first line of treatment involves medications, but there are other treatments which may be appropriate (e.g., catheter ablation, an atrioventricular node ablation, cardiac surgical ablation, or cardioversion).

**Cardiac Resynchronization Therapy (CRT)**

Despite the combination of various therapies for heart failure, some patients remain refractory to full medical treatment. Of the various nonpharmacological approaches, biventricular pacing or CRT has gained interest since its introduction in the early 1990s. CRT is the term applied to reestablishing synchronous contraction between the left ventricular free wall and the ventricular septum in an attempt to improve left ventricular efficiency and, subsequently, to improve functional class. Generally, CRT has been used to describe biventricular pacing, but cardiac resynchronization can be achieved by left ventricular pacing only in some patients. Selected patients with mild to severe heart failure may benefit from CRT or biventricular pacing. CRT, in combination with stable optimal medical therapy, may help the lower chambers of the heart beat together and improve the heart's ability to supply blood and oxygen to the body. CRT is designed to help the right and left ventricle (LV)s beat at the same time in a normal sequence treating ventricular dyssynchrony.

An implantable biventricular pacemaker is an advanced version of a standardized implantable pacemaker. The biventricular pacemaker is implanted in the muscle tissue of the chest, below the collarbone, or in the abdomen. Three leads or wires, one atrial lead and two ventricular leads, are transvenously connected from the pacemaker to both sides of the heart. In a small percentage of cases, it may not be possible to place the left ventricular lead transvenously. In such situations, some centers are opting for an epicardial approach if the transvenous approach is unsuccessful. The pacemaker sends out electrical impulses to the heart through the leads. Placement of a biventricular pacemaker can usually be accomplished in an outpatient setting under sedation or general anesthesia. A short inpatient stay may be required for epicardial left ventricular lead placement. Once the pacemaker is implanted, it is programmed so that both ventricles are stimulated to contract after atrial contraction with the goal of improving left ventricle function, reducing presystolic mitral regurgitation and improving LV diastolic filling time.

The benefits of CRT need to be weighed against the risks of the procedure along with the adverse effects of having a CRT device implanted long term. The reported risks of the procedure are uncommon but some events
may be serious such as pericardial effusion with tamponade or coronary dissection. Minor reported adverse events such as lead dislodgement are more common and may involve some degree of morbidity and result in repeat procedures.

**CRT plus Implantable Cardioverter Defibrillator (ICD) System (CRT-D)**

Some individuals with heart failure are also at high risk for life-threatening heart rhythms, ventricular tachycardia or ventricular fibrillation. Patients with heart failure who are at high risk for ventricular tachycardia and ventricular fibrillation may require a CRT system that includes implantable cardioverter defibrillator (ICD) therapy. The CRT plus ICD system (CRT-D) is designed to help the two lower heart chambers, the right and LVs, beat at the same time in a normal sequence, treating ventricular dyssynchrony. Additionally, should an individual experience an episode of ventricular tachycardia or ventricular fibrillation, the CRT-D system will detect the life-threatening arrhythmia and automatically correct the heart’s rhythm.

**Contraindications**

Contraindications to biventricular pacemakers (CRT) or combination resynchronization-defibrillator devices are:

- Asynchronous pacing is contraindicated in the presence or likelihood of competitive paced and intrinsic rhythms.
- Unipolar pacing is contraindicated in individuals with an ICD because it may cause unwanted delivery or inhibition of defibrillator or ICD therapy.
- CRT-D devices are contraindicated for patients whose ventricular tachyarrhythmias may have transient or reversible causes and for patients with incessant ventricular tachycardia or ventricular fibrillation.
- CRT-D devices are contraindicated for dual chamber atrial pacing in patients with chronic refractory atrial tachyarrhythmias.

CRT-D may be considered for people who fulfill the criteria for implantation of a CRT-pacing (P) device and who also separately fulfill the criteria for the use of an ICD device.

**Replacement of Device**

When a biventricular pacemaker nears the end of battery life it is replaced; the expected lifespan of biventricular pacemaker pulse generator varies among manufacturers. In addition, leads may become dislodged or fracture and require replacement.

**U.S. Food and Drug Administration (FDA)**

Multiple biventricular pacemakers have been approved by the U.S. Food and Drug Administration (FDA) through the Premarket Approval (PMA) process for biventricular pacing alone (CRT) or biventricular pacing and defibrillation (CRT-D). Manufacturers of biventricular devices include St. Jude Medical (Sunnyvale, CA), Medtronic (Minneapolis, MN), Guidant Corp. (St. Paul, MN), and ELA Medical, Inc. (Plymouth, MN).

**Literature Review**

Evidence in the published peer-reviewed literature, including randomized controlled trials and meta-analysis and systematic reviews, indicates that biventricular resynchronization therapy is effective at improving quality of life, patient functional capacity and heart failure symptoms among a subgroup of patients with heart failure, with or without ICD indications, decreased cardiac function and ventricular dyssynchrony who are on optimal pharmacologic regimen before implantation (Deng, et al., 2015; Cleland, et al., 2009; Upadhyay, et al., 2008; Auricchio, et al., 2007; McAlister, et al., 2007; Lindenfeld, et al., 2007; Delnoy, et al., 2007; Sutton, et al., 2006; Gasparini, et al., 2006; Cleland, et al., 2005; Molhoek, et al., 2005; Doshi, et al., 2005; Molhoek, et al., 2004; Bristow, et al., 2004; Garrigue, et al., 2003; Abraham, et al., 2002; Leclercq, et al., 2002; Leone, et al., 2002).

The majority of new research in CRT is to evaluate whether the benefits of CRT extend to patients with mild or less severe heart failure (NYHA Class I/II). Four key randomized, controlled trials Resynchronization–Defibrillation for Ambulatory Heart Failure Trial (RAFT), Resynchronization Reverses Remodeling in Systolic Left Ventricular Dysfunction (REVERSE), Multicenter InSync ICD Randomized Clinical Evaluation II (MIRACLE ICD II) and Multicenter Automatic Defibrillator Implantation Trial with Cardiac Resynchronization Therapy (MADIT-CRT) enrolling 4414 patients which included patients with NYHA Class I or II heart failure enrolling at least 25 patients per treatment group reporting on at least one relevant health outcome with follow-up ranging from six
months to 2.4 years have been published in the peer-reviewed literature (Tang, et al., 2010; Moss, et al., 2009; Linde, et al., 2008, Abraham, et al., 2004).

Evidence in the published peer-reviewed literature, including randomized controlled trials and a meta-analysis (Al-Majed, et al., 2011), indicates that there is a consistent benefit for CRT in reducing hospitalizations for a subgroup of patients with mild heart failure (NYHA Class I or II) and in improving echocardiographic parameters. Data indicates that biventricular resynchronization therapy does not demonstrate benefit on quality of life, functional status, or progression to more advanced stages of heart failure. The evidence on mortality differs among the available studies. Of the two largest studies, MADIT-CRT and RAFT, one reported a mortality difference while the other does not. The RAFT trial had patients with more severe illness, a higher baseline death rate, and a longer follow-up period concluding that CRT is likely to improve mortality for patients with NYHA class II heart failure. Robust evidence to support biventricular resynchronization therapy in patients with asymptomatic left ventricular dysfunction or NYHA Class I symptoms is inconclusive resulting in the inability to draw strong conclusions regarding the impact on health outcomes (Santangeli, et al., 2011; Al -Majed, et al., 2011, Adabag, et al., 2011; Zareba, et al., 2011, Versteeg, et al., 2011; Pouleur, et al., 2011, Solomon, et al., 2010, Tang, et al., 2010; Moss, et al., 2009; Linde, et al., 2008, Abraham, et al., 2004).

Literature Review Patient Selection Criteria
It has been reported that approximately 30% of the patients who are selected for therapy, according to the current criteria, do not benefit from CRT (Stavrakis, et al., 2012). A variety of factors have been proposed as contributing to the nonresponder rate associated with CRT, including suboptimal left ventricular lead placement, suboptimal atrioventricular (AV) and ventricle-to-ventricle (V-V) timing, ventricular scar, and heart failure disease progression (Abraham, 2019). Since some patients do not respond favorably after undergoing CRT, studies addressing optimal patient selection criteria for CRT are ongoing.

A recent review of indications for CRT reported that there are inconsistencies in guideline recommendations for CRT indications which is due to limited evidence of CRT benefit in these patients. Two areas that have a paucity of evidence in the published peer-reviewed literature include management of patients with atrial fibrillation and the choice of the most appropriate device (i.e., pacemaker CRT vs. defibrillator CRT) (Normand, et al., 2018).

QRS Duration: A recent meta-analysis reported that in patients with intrinsic QRS duration ≥ 150 ms, pooled analysis of five randomized controlled trials revealed a significant 42% reduction in the incidence of the primary endpoint of death or hospitalization for HF with the use of CRT compared to control (Stavrakis, et al., 2012).

Some patients with narrow QRS complexes have echocardiographic evidence of left ventricular mechanical dyssynchrony and may also benefit from CRT. Results of published trials are insufficient at this time to demonstrate that use of CRT in heart failure patients with a narrow QRS complex (i.e., < 120 ms) benefits patient outcomes.

The Evaluation of Resynchronization Therapy for Heart Failure (LESSER-EARTH) trial was a randomized, double-blind, 12-center study that was designed to compare the effects of active and inactive cardiac resynchronization therapy in patients with severe left ventricular dysfunction and a QRS duration <120 ms (Thibault, et al., 2013). The trial was interrupted prematurely by the Data Safety and Monitoring Board because of futility and safety concerns after 85 patients were randomized. The authors reported that in patients with a LVEF ≤35%, symptoms of heart failure, and a QRS duration <120 ms, CRT did not improve clinical outcomes or left ventricular remodeling and was associated with potential harm (Thibault, et al., 2013).

In a prospective randomized clinical trial, Beshai et al. (2007) enrolled 172 patients who had a standard indication for an ICD. Patients received the CRT device and were randomly assigned to the CRT group or to a control group (no CRT) for six months. The primary end point was the proportion of patients with an increase in peak oxygen consumption of at least 1.0 ml per kilogram of body weight per minute during cardiopulmonary exercise testing at six months. At six months, the CRT group and the control group did not differ significantly in the proportion of patients with the primary end point (46% and 41%, respectively). In a prespecified subgroup with a QRS interval of ≥ 120 ms, the peak oxygen consumption increased in the CRT group (p=0.02), but it was unchanged in a subgroup with a QRS interval of ≤ 120 ms (p=0.45). There were 24 heart failure events requiring intravenous therapy in 14 patients in the CRT group (16.1%) and 41 events in 19 patients in the control group.
(22.3%), but the difference was not significant. The authors reported that CRT did not improve peak oxygen consumption in patients with moderate-to-severe heart failure, providing evidence that patients with heart failure and narrow QRS intervals may not benefit from CRT.

Patients with narrow QRS complex are currently not eligible for CRT, and the potential effects of CRT are not well-studied. In a prospective pilot study, Bleeker et al. (2006a) studied the effects of CRT in heart failure patients with narrow QRS complex (<120 ms) and evidence of LV dyssynchrony on tissue Doppler imaging (TDI). The study participants included a total of 33 consecutive patients with narrow QRS complex and 33 consecutive patients with wide QRS complex (control group). Patient inclusion criteria included: LV dyssynchrony ≥ 65 ms on TDI, NYHA functional Class III/IV heart failure, and LVEF ≤ 35%. Baseline characteristics, particularly LV dyssynchrony, were comparable between patients with narrow and wide QRS complex (p=NS). No significant relationship was observed between baseline QRS duration and LV dyssynchrony (p=NS). The improvement in clinical symptoms and LV reverse remodeling was comparable between patients with narrow and wide QRS complex (mean NYHA functional class reduction 0.9 versus 1.1 (p=NS) and mean LV end-systolic volume reduction 39 versus 44 ml (p=NS). The authors reported that, “CRT appears to be beneficial in patients with narrow QRS complex and severe LV dyssynchrony on TDI, with similar improvement in symptoms and comparable LV reverse remodeling. These effects need confirmation in studies with larger populations.” The authors noted that color-coded TDI measures the velocity of the myocardium, which may not always equal active myocardial contraction. Large, comparative studies are needed to define which technique is most accurate in the assessment of LV dyssynchrony.

QRS Duration Meta-Analysis: Stavrakis et al. (2012) conducted a meta-analysis of randomized clinical trials to evaluate the impact of QRS duration on the efficacy of CRT. Only trials that reported subgroup data according to QRS duration were included. Five trials (Tang, et al., 2010; Moss, et al., 2009; Linde, et al., 2008; Cleland, et al., 2005; Bristow, et al., 2004) involving 6501 patients (4437 with QRS ≥ 150 ms and 2064 with QRS < 150 ms) were included. Three trials, enrolling patients with mild to moderate HF, compared CRT-implantable cardioverter defibrillator with CRT, whereas CRT versus medical therapy was compared in the other two trials, which included patients with advanced HF. In patients with intrinsic QRS duration ≥ 150 ms, pooled analysis of the five trials revealed a significant 42% reduction in the incidence of the of the primary endpoint of death or hospitalization for HF with the use of CRT compared to control (HR = 0.58, 95% CI: 0.50-0.68; p<0.00001), but not in patients with QRS < 150 ms (HR = 0.95, 95% CI: 0.83-1.10; p=0.51). These results were consistent across all degrees of HF severity. In patients with intrinsic QRS duration <150 ms, pooled analysis of the five trials showed no significant benefit from CRT (with or without ICD) compared to control (HR = 0.95, 95% CI: 0.83–1.10; p=0.51). The lack of benefit was consistent between the two subgroups based on the severity of heart failure. There was no heterogeneity between the trials.

Sipahi et al. (2011) conducted a meta-analysis of published randomized controlled trials that evaluated whether patients with modest prolongations of the QRS complex benefited from CRT. This study identified five trials enrolling a total of 5813 patients that reported on outcomes stratified by QRS duration. There was some variability in the definition of QRS categories, but the authors were able to categorize studies into those with moderately prolonged QRS, generally 120-149 msec, and severely prolonged QRS, generally ≥150 msec. For patients with a moderately prolonged QRS, there was no significant benefit for CRT in reducing composite outcomes of adverse cardiac events (Risk ratio [RR]: 0.95, 95% CI: 0.82 to 1.10, p=0.49). In contrast, for patients with a severely prolonged QRS, there was a 40% relative reduction in the composite outcomes (RR: 0.60, 95% CI: 0.53 to 0.67, p<0.001). Multiple limitations to these findings were reported including use of summary versus individual data in the meta-analysis; use of heterogeneous enrollment criteria by the five included trials with variable composite outcome measures; unknown morphology of the QRS complex in participants with a QRS duration less than 150 msec. and unknown percentages of study participants with RBBB (right bundle branch block). The authors reported that further analysis of individual subject-specific data from all relevant clinical trials can further refine the QRS cutoffs for different types of conduction abnormalities.

QRS Morphology: In a retrospective study, Dupont et al. (2012) evaluated the relative impact of QRS morphology and duration in echocardiographic responses to CRT and clinical outcomes. Baseline characteristics, clinical and echocardiographic response, and outcomes of all patients who received CRT at a single center were evaluated. Patients were stratified into four groups according to their baseline QRS morphology and QRS duration. A total of 496 patients were included in the study; 216 (43.5%) had LBBB and a
QRS 150 ≥ ms, 85 (17.1%) had LBBB and QRS < 150 ms, 92 (18.5%) had non-LBBB and a QRS ≥150 ms, and 103 (20.8%) had non-LBBB and QRS <150 ms. Echocardiographic response (change in ejection fraction) was better in patients with LBBB and QRS ≥150 than in those with LBBB and QRS < 150 ms, non-LBBB and QRS ≥150, and non-LBBB and QRS >150 ms (p<0.0001). In a multivariate stepwise model with change in ejection fraction as the dependent variable, the presented classification was the most important independent variable (p=0.0003). Long-term survival was better in LBBB patients with QRS ≥150 (p=0.02), but this difference was not significant after adjustment for other baseline characteristics (p=0.15) suggesting that comorbid conditions may confound the treatment responses. The authors stated that “due to the lack of sufficiently powered trials in these subgroups, guideline committees have the difficult task of using this and similar studies to refine patient selection for CRT”.

In a meta-analysis, Sipah et al. (2012) evaluated the effect of CRT on clinical events (including death and heart failure hospitalizations) with regards to bundle branch block morphologies. Four randomized controlled trials totaling 5356 patients met the inclusion criteria. The authors reported that in patients with a LBBB, CRT was very effective in reducing adverse events with a relative risk reduction of 36% (p=0.00001). However, no benefit was observed in patients with other types of conduction abnormalities and a QRS duration > 120 milliseconds.

**Echocardiography:** Echocardiographic and Doppler imaging techniques have emerged to play a potential role in the care of the patient with CRT. Since some patients do not respond favorably after undergoing CRT, it has been suggested that one reason for nonresponse to CRT is that the ECG widened QRS is a suboptimal marker for dyssynchrony. The echocardiographic quantification of dyssynchrony may potentially play a role in improving patient selection for CRT (Diab, et al., 2011, Gorscan, et al., 2008).

**Triple-site CRT (Triventricular Pacing)**

Triple-site cardiac resynchronization or triventricular pacing involves the addition of an additional ventricular pacing lead. The right ventricular and atrial leads are implanted as in conventional CRT. The third ventricular lead is joined in parallel with a Y-connector and connected to the left ventricular port of the CRT system.

Triventricular pacing has been proposed as an alternative approach to improve the response rate in CRT recipients. It has been suggested that failure of response to biventricular pacing is probably due to a combination of factors including placement of the pacing lead over a zone of slow conduction, the presence of scar within the left ventricle, variable electrical response of the diseased ventricle to pacing, or suboptimal positioning of the pacing leads with regard to the area of latest contraction (Rogers, et al., 2012).

**Literature Review**

There is a paucity of randomized controlled clinical trials or comparative studies in the peer-reviewed literature assessing the impact of triple-site resynchronization on long-term health outcomes in patients compared to conventional biventricular pacing (Bordachar, et al., 2019; Marques, et al., 2018; Zhang, et al., 2018; Anselme, et al., 2016; Rogers, et al., 2012; Lenarczyk, et al., 2012).

Bordachar et al. (2019) conducted a multicenter parallel randomized prospective trial (V3 trial) (n=84) to assess the feasibility and safety of adding a second left ventricular (LV) lead to CRT nonresponders and its clinical impact. The trial enrolled patients that were eligible for a CRT system and considered as nonresponders as per clinical composite score (CCS). They were randomized to the V3 arm (implantation of an additional LV lead; n=43) or control arm (no change; N=41). Implant success rate, incidence of severe adverse events, CCS, and secondary clinical and echocardiographic end points were evaluated at 12 and 24 months. Positioning of a second LV lead was successful at first (40 of 44 - 90.9%) or second (4 of 44 - 9.09%) attempt. The perioperative complication rate (infection, system explant, pneumothorax, and hematoma) was high (procedures or system-related complications for nine patients- 20.4%). After 24 months, 35 systems (79.5%) were working properly. V3 treatment had no significant influence (p=0.27) on the CCS, number of heart failure hospitalizations, time to first heart failure hospitalization, New York Heart Association class, and LV ejection fraction at 12 and 24 months. The authors reported that although addition of a second LV lead in CRT nonresponders is feasible with a high success rate, this approach is associated with a significant rate of severe adverse events and does not provide significant long-term clinical benefits (ClinicalTrials.gov Identifier No. NCT01059175).
Anselme et al. (2016) conducted a pilot multicenter randomized study (n=76) to assess the safety and feasibility of triple-site ventricular stimulation (TRIV) with two right ventricular leads and one left ventricular lead compared to conventional CRT. The primary end-point was the rate of severe adverse events at six months. Secondary end-points included functional improvement parameters, quality-of-life (QOL) score, and changes of echocardiographic indices at six and 12 months in a subset of patients. All implant procedures but one were successful. At six months, there was no statistical difference between proportions of patients with at least one severe adverse event in both groups (34.1% versus 25.7%). There was no difference between functional improvement parameters, 6-minute walking distances, QOL scores, and echographic indices. At 12 months, the proportions of patients with a left ventricular ejection fraction gain of more than 5%, 10%, or 15% were significantly superior with TRIV. This study is limited by the small sample size and short-term follow-up.

Rogers et al. (2012) performed a double-blind randomized controlled trial in 43 patients referred for CRT. All patients had three leads implanted, but patients in the conventional CRT arm had their device programmed to biventricular pacing. The 12-month follow-up period was completed by 37 patients. The triventricular group had greater improvements in the 6-minute walk distance compared to the conventional CRT group (increase of 82 minutes versus 56 minutes, p=0.008), and greater improvement on the Minnesota Living with Heart Failure scale (reduction of 24 points versus 18 points, p<0.0001). Complications did not differ between groups; however, since all patients had 3 leads implanted, this was not a valid comparison of complications for biventricular versus triventricular pacing.

In a randomized controlled trial, Lenarczyk et al. (2012) reported on the first 100 patients randomized to triple-site or conventional CRT in the Triple-Site versus Standard Cardiac Resynchronization Therapy Randomized Trial (TRUST CRT). After a follow-up of one year, more patients in the conventional CRT arm were in NYHA class III or IV heart failure compared to the triple-site CRT group (30% versus 12.5%, p<0.05). Implantation success was similar in the triple-site and conventional groups (94% versus 98%, respectively, p=NS), but the triple-site implantation was associated with longer time for implantation and a higher fluoroscopic exposure. In addition, more patients in the triple-site group required additional procedures (33% versus 16%, p<0.05). Triple-site CRT was associated with higher radiation exposure and a greater number of additional procedures post-implantation.

Zhang et al. (2018) conducted a meta-analysis of randomized controlled trials (RCTs) and comparative observational studies (n=251) comparing the benefits of triple-site ventricular (Tri-V pacing) versus Bi-V pacing on the left ventricular (LV) remodeling, quality of life, and exercise capacity in patients with heart failure (HF). The meta-analysis included one RCT, two randomized crossover studies, and two nonrandomized comparative studies. Two different pacing modalities were used. One type used one lead in the right ventricle and leads in two different tributaries in the left ventricle. The other used two leads in the right ventricle. Patients in the triple-site pacing group had greater improvement in LVEF (p<0.001) and NYHA classes (p=0.001) compared with the control group. There were no significant differences in left ventricular geometry, six-min walk distance, or Minnesota Living With Heart Failure Questionnaire score between the two groups. The subgroup analyses showed there might be a greater improvement in LVEF in the Tri-V pacing group in patients with QRS duration ≥ 155 ms (p<0.001). The studies were limited by small sample size, short-term follow-up and lack of randomization. No study in this met-analysis had power to assess the benefits of Tri-V pacing in terms of mortality, mobility, or other clinical outcomes.

**CRT with Wireless Left Ventricle Endocardial Pacing**

The WiSE Cardiac ResynchronizationTherapy System® (ebrSystems©; Sunnyvale, CA) is a wireless left ventricle (LV) pacing system that works with a conventional pacemaker and/or defibrillator for individuals in whom CRT is indicated. The WiSE CRT System is proposed to be used for patients who have failed conventional CRT or are not candidates for coronary sinus lead placement. The WiSE CRT system eliminates the need for a LV pacing wire in the coronary sinus. An ultrasonic transmitter attached to a battery unit and a tiny wireless receiver, measuring 10x2.6mm acts as a pacing electrode. The transmitter is implanted in a left intercostal space, and the electrode is inserted into the LV via a retrograde aortic approach in a catheter-based procedure. After pacing-sensing mapping of the LV for site selection, the electrode is attached to the endocardial surface with a fixation barb. Sensing of RV pacing output from the conventional pacemaker device triggers ultrasonic energy transmission to the LV electrode from the transmitter, which stimulates synchronous contraction of the LV. The system allows the provider to customize electrode placement to the optimal location for pacing, which varies
among patients; this differs significantly from conventional LV pacing leads, which are limited by coronary sinus anatomy (Hayes, 2019).

The WiSE CRT System has received FDA Investigational Device Exemption (IDE) approval. The U.S. pivotal Stimulation Of the Left Ventricle Endocardially (SOLVE) CRT study began in January 2018. This prospective, randomized controlled study will evaluate the WiSE CRT System in patients with an indication for implantation of a CRT-defibrillator device. The anticipated enrollment in the trial is 350 participants. These patients must have either failed conventional CRT or have been previously untreated with conventional CRT systems. There have been a limited number of studies published in the peer-reviewed literature addressing the use of this technology (Singh, et al., 2019; Reddy, et al., 2017; Hayes, 2019; Gamble, et al., 2018; Auricchio, et al., 2014; ClinicalTrials.gov [NCT02922036]).

His Bundle Pacing (HBP)
His bundle pacing (HBP) is an alternative approach to RV and biventricular pacing and is performed with the aim of maintaining a physiological pattern of ventricular activation via the native His-Purkinje system. CRT with coronary sinus (CS) lead placement has become established as a first-line treatment for a subset of patients. Despite the development of sophisticated tool sets to facilitate implant and intraprocedural strategies that have evolved to consider mechanical and electrical delay in LV lead targeting, rates of nonresponse to CRT remain high between 30% and 40%. Rates of implant failure for CRT range between 5% and 9%, in part due to high rates of CS lead dislodgement (3% to 7% reported across major trials). Alternative strategies to achieve resynchronization have been explored, including permanent HBP. Permanent HBP was initially performed using standard pacing leads by reshaping the stylet or using a deflectable stylet to precisely position the lead at a site near the electrophysiology mapping catheter demonstrating the largest His deflection. This approach was technically challenging and time consuming. There has been development of a specialized pacing lead (e.g., SelectSecure 3830; Medtronic, Minneapolis, MN) and sheath (e.g., C315His, C304 SelectSite; Medtronic). Case reports and review articles report that HBP may an alternative approach in an attempt to achieve cardiac resynchronization in technically challenging cases where the standard endovascular approach via the coronary sinus is not possible (Lewis, et al., 2019; Vijayaraman, 2018).

Ali et al. (2018) concluded in a report on HBP that there is currently limited published data available for His pacing in any clinical setting. Although pacing thresholds for His pacing in bradycardia appear to be stable, there is limited long-term follow-up data available. When His pacing is used to deliver ventricular resynchronization in patients with bundle branch block, the pacing thresholds can be relatively high, though comparable to left ventricular pacing thresholds. This has the potential implications on battery longevity, though pacing is only required via a single lead (compared to biventricular pacing). Success rates for His lead implantation have been as low as 60% without dedicated tools and experience. Success rates have improved with the development of dedicated tools; however, the range of tools currently available are still limited, and these could be further improved. Adequately powered randomized control trials are required to investigate whether the theoretical advantages of physiological ventricular activation are achieved with His pacing and if the encouraging results in observational studies translate into clinical benefit (Ali, et al., 2018).

Ezzeddine et al. (2018) report that certain problems unique to HBP are faced with conventional active fixation pacing leads, including a higher pacing threshold owing to the fibrous structure of the His bundle and due to current limitations in lead design and delivery. In addition, higher pacing thresholds can lead to increased battery drain and shorter battery longevity compared with traditional RV pacing. Other limitations of permanent HBP include inability to perform lead implantation in 10%-20% of patients, particularly in patients with dilated and remodeled atria or other structural heart disease, which makes mapping of the His bundle and delivery of the lead difficult. Ventricular undersensing, atrial oversensing on the ventricular channel, and atrial capture can also occur and need to be carefully avoided or excluded at the time of implantation. Long-term randomized safety and efficacy data are needed.

A 2019 UptoDate report on nonpharmacologic therapy for the control of ventricular rate in atrial fibrillation addresses HBP as an investigational method. The report states that a potential alternative to CRT is the positioning of a single pacing lead near the His bundle. It is technically difficult to place a conventional pacing lead in a position that results in capture of the His bundle at a reasonable pacing output because the His-bundle is insulated from the endocardium. Newer, small caliber, screw-in pacing leads that are delivered using a guiding
sheath rather than a stylet may improve the ability to accomplish permanent His bundle capture. The report states that further studies in larger populations are necessary to clarify both the clinical benefits and safety of HBP. Also, given the risks of lead dislodgement, the safety and efficacy of HBP should be compared against biventricular pacing (Ganz, 2019).

There is a dearth of guidelines that address HBP. The European Society of Cardiologists include HBP in their guideline on cardiac pacing. They are unable to give definite recommendations until the results of larger trials become available (Brignole, et al., 2013).

HBP needs to be compared directly with CRT with traditional CS or epicardial LV leads to assess clinical impact. The ongoing His Bundle Pacing Versus Coronary Sinus Pacing for Cardiac Resynchronization Therapy (His-SYNC) (NCT02700425) comparing HBP to conventional CRT with biventricular pacing is evaluating this question. Two other acute studies in patients with heart failure (HF) are also under way: the Electrical Resynchronization and Acute Hemodynamic Effects of Direct His Bundle Pacing Compared to Biventricular Pacing study (NCT03452462) will use noninvasive electrocardiographic imaging to compare and His Bundle Pacing in Bradycardia and Heart Failure (NCT03008291) will evaluate acute electrocardiographic metrics with HBP in patients undergoing CRT or dual-chamber implants. Other trials are exploring related questions in CRT-eligible patients (Upadhyay, et al., 2019; ClinicalTrials.gov).

Literature Review
There is a paucity of large randomized controlled clinical trials or comparative studies in the peer-reviewed literature assessing the impact of HBP on long-term health outcomes in patients compared to conventional biventricular pacing with traditional coronary sinus or epicardial LV leads (Qian, 2019; Boczar, et al., 2019, 2018; Sharma, et al., 2018, 2017; Ezzeddine, et al., 2018; Vijayaraman, 2018; Bhatt, et al., 2017; Teng, et al., 2016).

Qian et al. (2019) conducted a systematic review and meta-analysis evaluate the efficacy of HBP in patients with heart failure and LV dyssynchrony. The successful rate of implantation, QRS duration, pacing threshold, LV function at baseline and follow-up, and mortality rates were extracted and summarized. Eleven studies including 494 patients were included in this analysis. The average age of the patients was 71.9 years and 63.2% of patients were male. Patients with ischemic etiology accounted for 32.8% of the population. Four studies reported 173 patients with AF and cardiomyopathy undergoing AV node ablation. The other seven studies focused on CRT candidates including de novo implantation, CRT nonresponders, patients with pacing-induced cardiomyopathy, and failed LV lead placement. The overall successful rate for implantation was 82.4%. The main indications for HBP were CRT candidates and cardiomyopathy with atrial fibrillation undergoing atrioventricular node ablation. Permanent HBP resulted in narrow QRS duration of 116.3 ± 13.9 ms after implantation. LV functions, including echocardiographic parameters and clinical outcomes, significantly improved at follow-up (p<0.001). However, there was a trend of increased capture and bundle branch block correction thresholds at follow-up compared to baseline (p=0.01 and 0.02, respectively). During a mean follow-up of 23.7 months, 5.9% of the patients experienced heart failure-related hospitalization and the mortality rate was 9.1%. The authors reported limitations of this meta-analysis include the limited sample size and most of the studies were cohort studies with inherent limitations that reduced the internal validity compared to randomized controlled trials. Second, there are limited data on the effect size of HBP on outcomes as the studies included were observational and did not all have comparative arms. Next, some data, including pacing pulse width and follow-up time, were variable and inconsistent, which may influence the study uniformity. In addition, there was no uniformity in measuring QRS durations with selective and nonselective HBP. The authors concluded that although HBP has shown promising results in small and nonrandomized studies in several clinical situations, long-term safety and pacing threshold are needed. Randomized controlled trials are needed to assess the efficacy of HBP in heart failure patients.

Professional Societies/Organizations
Professional society recommendations have been published or updated in an effort to guide appropriate care/indications to scenarios for which clinical trial evidence and/or clinical experience was available that support device implantation for CRT.

American College of Cardiology Foundation (ACCF), Heart Rhythm Society (HRS), American Heart Association (AHA), American Society of Echocardiography (ASE), Heart Failure Society of America
The 2013 ACCF/HRS/AHA/ASE/HFSA/SCAI/SCCT/SCMR document addresses the appropriate use of implantable cardioverter-defibrillators (ICDs) and cardiac resynchronization therapy (CRT) for selected patient populations (Russo, et al., 2013). The authors’ state that the appropriate use criteria should be used in conjunction with the ACC/AHA/HRS 2008 Guidelines for Device-Based Therapy of Cardiac Rhythm Abnormalities and the 2012 focused update (Epstein, et al., 2008; Tracy, et al., 2012).

The final score reflects the median score of the 17 technical panel members and has been labeled according to the categories of Appropriate (median 7 to 9), May Be Appropriate (median 4 to 6), and Rarely Appropriate (median 1 to 3). The authors state that “The relationship of these criteria to existing guidelines was provided to the technical panel. In addition, extensive links to clinical trials and other literature regarding the role of ICD and CRT in each clinical scenario were provided to technical panel members. This document represents the current understanding of the clinical utility of ICD and CRT implantation in clinical practice as measured by physicians with a variety of backgrounds and areas of expertise. It is the goal that these criteria will help provide a guide to inform medical decisions and help clinicians and stakeholders understand areas of consensus as well as uncertainty, while identifying areas where there are gaps in knowledge that warrant additional investigation”.

The authors stated that, “Atrial arrhythmias (including atrial fibrillation, atrial flutter, and atrial tachycardia) are not included in the indication tables. There are fewer data available for CRT in patients with persistent atrial arrhythmias, and the writing group elected to avoid additional scenarios for practical reasons, as the document already includes a large number of scenarios. However, it is assumed that the presence of intermittent or persistent atrial arrhythmias would not preclude CRT implantation, and the benefits of CRT would also apply to patients with persistent atrial arrhythmias, as long as CRT is maintained nearly 100% of the time”.

Ambulatory class IV is defined as class IV heart failure with: 1) no active acute coronary syndrome; 2) no inotropes; and 3) on guideline-direct medical therapy (GDMT). A normal LVEF is defined as ≥ 50%. The authors state that, “GDMT for heart failure in the setting of LV systolic dysfunction requires individualization but typically should include the combination of an angiotensin-converting enzyme inhibitor or angiotensin receptor blocker and betablocker therapy adjusted to target doses as tolerated, with diuretics adjusted if/as needed to control fluid retention. In selected patients, the addition of aldosterone antagonists and hydralazine plus nitrate combinations should be considered. Patients who are going to receive substantial benefit from medical treatment alone usually show some clinical improvement during the first 3 to 6 months. Medical therapy is also assumed to include adequate rate control for tachyarrhythmias, including atrial fibrillation. Therefore, it is recommended that GDMT be provided for at least 3 months before planned reassessment of LV function to consider device implantation. If LV function improves to the point where primary prevention indications no longer apply, then device implantation is not indicated.

Recommendations are provided based on the following scoring method:

- Median score 7-9: Appropriate care: An appropriate option for management of patients in this population due to benefits generally outweighing risks; effective option for individual care plans, although not always necessary, depending on physician judgment and patient-specific preferences (i.e., procedure is generally acceptable and is generally reasonable for the indication).
- Median score 4-6: May be appropriate for care: At times an appropriate option for management of patients in this population due to variable evidence or agreement regarding the benefit/risk ratio, potential benefit based on practice experience in the absence of evidence, and/or variability in the population; effectiveness for individual care must be determined by a patient’s physician in consultation with the patient based on additional clinical variables and judgment along with patient preferences (i.e., procedure may be acceptable and may be reasonable for the indication).
- Median score 1-3: Rarely appropriate care: Rarely an appropriate option for management of patients in this population due to the lack of a clear benefit/risk advantage; rarely an effective option for individual care plans; exceptions should have documentation of the clinical reasons for proceeding
with this care option (i.e., procedure is not generally acceptable and is not generally reasonable for the indication).

Generally, criteria that have been deemed Appropriate or May Be Appropriate in these scenarios often meet Class I, IIa, or IIb criteria in guideline documents, are supported by a critical mass of existing data, or were deemed by the technical panel to meet sufficient clinical judgment to be reasonable and appropriate.

Indications rated as Appropriate or May be Appropriate are detailed below; indications rated as Rarely Appropriate (Median score 1-3) are outlined in the appropriate use criteria document described above.

The following indications were rated as appropriate care (median score 7-9):

Ischemic cardiomyopathy, left ventricular ejection fraction (LVEF) ≤ 30%, no prior implant, sinus rhythm (SR) for ANY of the following:

- QRS 120-149 milliseconds (ms), left bundle branch block (LBBB), New York Heart Association (NYHA) Class II (7), III-IV (8)
- QRS ≥ 150 ms, LBBB, NYHA Class I (7) II (8), III-IV (9)
- QRS ≥ 150 ms, non-LBBB, NYHA Class III-IV (7)

Ischemic cardiomyopathy, LVEF 31-35%, no prior implant, SR for ANY of the following:

- QRS 120-149 ms, LBBB, NYHA Class II (7), III-IV (8)
- QRS ≥ 150 ms, LBBB, NYHA Class II (8), III-IV (9)
- QRS ≥ 150 ms, non-LBBB, NYHA Class III-IV (7)

Nonischemic cardiomyopathy, LVEF ≤ 30%, no prior implant, SR for ANY of the following:

- QRS 120-149 ms, LBBB, NYHA Class II (7), III-IV (8)
- QRS ≥ 150 ms, LBBB, NYHA Class II (8), III-IV (9)
- QRS ≥ 150 ms, non-LBBB, NYHA Class III-IV (7)

Nonischemic cardiomyopathy, LVEF 31-35%, no prior implant, SR for ANY of the following:

- QRS 120-149 ms, LBBB, NYHA Class II (7), III-IV (8)
- QRS ≥ 150 ms, LBBB, NYHA Class II (8), III-IV (9)
- QRS ≥ 150 ms, non-LBBB, NYHA Class III-IV (7)

Pre-Existing or anticipated right ventricular (RV) pacing with a clinical indication for ICD or pacemaker implantation, intrinsic narrow QRS, LVEF ≤ 35% when RV pacing anticipated is > 40%, NYHA Class I-II (7), III-IV (8).

Refractory Class III/IV heart failure < 3 months post revascularization and/or ≤ 40 days post-myocardial infarction (MI), no other indication for ventricular pacing, LVEF ≤ 35% for ANY of the following:

- QRS 120-149 ms, LBBB (7)
- QRS ≥ 150 ms, LBBB (8)
- QRS ≥ 150 ms, non-LBBB (7)

The following indications were rated as may be appropriate for care (median score 4-6):

Ischemic cardiomyopathy, LVEF ≤ 30%, no prior implant, SR for ANY of the following:

- QRS 120-149 ms, LBBB, NYHA Class I (5)
- QRS 120-149 ms, non-LBBB, NYHA Class III-amb. IV (6)
• QRS ≥ 150 ms, non-LBBB, NYHA Class I (4), II (6)

Ischemic cardiomyopathy, LVEF 31-35%, no prior implant, SR for ANY of the following:

• QRS 120-149 ms, LBBB, NYHA Class I (5)
• QRS ≥ 150 ms, LBBB, NYHA Class I (6)
• QRS 120-149 ms, non-LBBB, NYHA Class III-IV (6)
• QRS ≥ 150 ms, non-LBBB, NYHA Class I (4), Class II (6)

Nonischemic cardiomyopathy, LVEF ≤ 30%, no prior implant, SR for ANY of the following:

• QRS 120-149 ms, LBBB, NYHA Class I (4)
• QRS ≥ 150 ms, LBBB, NYHA Class I (6)
• QRS 120-149 ms, non-LBBB, NYHA Class III-IV (6)
• QRS ≥ 150 ms, non-LBBB, NYHA Class I (5), II (6)

Nonischemic cardiomyopathy, LVEF 31-35%, no prior implant, SR for ANY of the following:

• QRS 120-149 ms, LBBB, NYHA Class I (5)
• QRS ≥ 150 ms, LBBB, NYHA Class I (6)
• QRS 120-149 ms, non-LBBB, NYHA Class III-IV (6)
• QRS ≥ 150 ms, non-LBBB, NYHA Class I (5), II (6)

LVEF > 35% of any etiology (ICD Indicated), no prior implant, SR:

• QRS 120-149 ms, LBBB, NYHA Class III-IV (4)
• QRS ≥ 150 ms, LBBB, NYHA Class I-II (4), III-IV (5)
• QRS ≥ 150 ms, non-LBBB, NYHA Class III-IV (4)

LVEF ≤ 35% of any etiology (NYHA Class IV on Intravenous Inotropic Support), no prior implant:

• QRS 120-149 ms, LBBB (6) or non-LBBB (4)
• QRS ≥ 150 ms, LBBB (6) or non-LBBB (5)

Pre-Existing or anticipated RV pacing with a clinical indication for ICD or pacemaker implantation-intrinsic narrow QRS:

• LVEF ≤ 35%, RV pacing anticipated ≤ 40%, NYHA Class I-II (4), III-amb. IV (5)
• LVEF > 35%, RV pacing anticipated ≤ 40%, NYHA Class III-IV (4)
• LVEF > 35%, RV pacing anticipated > 40%, NYHA Class I-II (5), III-IV (6)

Refractory Class III/IV heart failure < 3 months post revascularization and/or ≤ 40 days post-MI, no other indication for ventricular pacing:

• LVEF ≤ 35%, QRS 120-149 ms, non-LBBB (5)
• LVEF 36-50%, QRS ≥ 150, LBBB (4)

American College of Cardiology Foundation (ACCF), American Heart Association (AHA) and Heart Rhythm Society (HRS) Guideline for Device-Based Therapy for Cardiac Rhythm Abnormalities

The 2012 ACCF/AHA/HRS focused update incorporated into the ACCF/AHA/HRS 2008 guidelines for device-based therapy of cardiac rhythm abnormalities addresses recommendations for CRT (Epstein, et al., 2013; Tracy, et al., 2012). Guideline recommendations are classified as Class I, Class IIa, Class IIb, and Class III. The classification system is described as follows:
- Class I: Benefit >>> Risk; Procedure/Treatment should be performed/administered
- Class IIa: Benefit >> Risk; Additional studies with focused objectives needed. It is reasonable to perform procedure/administer treatment
- Class IIb: Benefit ≥ Risk; Additional studies with broad objectives needed; additional registry data would be helpful. Procedure/treatment may be considered.
- Class III: No Benefit or No Harm
  - Class of Recommendation (COR) III: No Benefit
    - Procedure/Test: not helpful
    - Treatment: no proven benefit
  - COR III: Harm
    - Procedure/Test: excess cost w/o benefit or harmful
    - Treatment: harmful to patients

The weight of evidence supporting each recommendation is classified as follows:

- Level A: Multiple populations evaluated. Data derived from multiple randomized clinical trials or meta-analyses.
- Level B: Limited populations evaluated. Data derived from a single randomized trial or nonrandomized studies.
- Level C: Very limited populations evaluated. Only consensus opinion of experts, case studies, or standard of care.

The updated guideline proposes several changes in recommendations for CRT, compared with the 2008 document. The most significant changes are limitation of the Class I indication to patients with QRS duration ≥150 ms; limitation of the Class I indication to patients with left bundle-branch block (LBBB) pattern; expansion of Class I indication to New York Heart Association (NYHA) class II (and with LBBB with QRS duration ≥150 ms); and the addition of a Class IIb recommendation for patients who have LVEF ≤30%, ischemic etiology of heart failure (HF), sinus rhythm, LBBB with a QRS duration ≥150 ms, and NYHA class I symptoms.

The following recommendations for CRT placement are included in the 2012 guideline:

Class I
- CRT is indicated for patients who have LVEF ≤ 35%, sinus rhythm, LBBB with a QRS duration ≥ 150 ms, and NYHA class II (Moss, et al., 2009, Tang, et al., 2010) III, or ambulatory IV (Abraham, et al., 2002; Bristow, et al., 2004; Cleland, et al., 2005; Moss, et al., 2009; Tang, et al., 2010; Linde, et al., 2008) symptoms on guideline directed medical therapy (GDMT) (Level of Evidence: A for NYHA class III/IV; Level of Evidence: B for NYHA class II).

Class IIa
- CRT can be useful for patients who have LVEF ≤ 35%, sinus rhythm, LBBB with a QRS duration 120 to 149 ms, and NYHA class II, III, or ambulatory IV symptoms on GDMT (Abraham, et al., 2002; Bristow, et al., 2004; Cleland, et al., 2005; Moss, et al., 2009; Tang, et al., 2010; Linde, et al., 2008) (Level of Evidence: B).
- CRT can be useful for patients who have LVEF ≤ 35%, sinus rhythm, a non-LBBB pattern with a QRS ≥ 150 ms, and NYHA class III/ambulatory class IV symptoms on GDMT (Abraham, et al., 2002; Bristow, et al., 2004; Cleland, et al., 2005; Tang, et al., 2010) (Level of Evidence: A).
- CRT can be useful in patients with atrial fibrillation and LVEF ≤ 35% on GDMT if the patient requires ventricular pacing or otherwise meets CRT criteria and b) AV nodal ablation or pharmacologic rate control will allow near 100% ventricular pacing with CRT (Brignole, et al., 2005; Brignole, et al., 2011; Doshi, et al., 2005; Wilton, et al., 2011; Upadhyay, et al., 2008) (Level of Evidence: B).
- CRT can be useful for patients on GDMT who have LVEF ≤ 35% and are undergoing new or replacement device placement with anticipated requirement for significant (> 40%) ventricular pacing (Doshi, et al., 2005; Wilkoff, et al., 2002; Adelstein, et al., 2011; Vatankulu, et al., 2009) (Level of Evidence: C).
Class IIb

- CRT may be considered for patients who have LVEF ≤ 30%, ischemic etiology of heart failure, sinus rhythm, LBBB with a QRS duration of ≥150 ms, and NYHA class I symptoms on GDMT (Moss, et al., 2009; Tang, et al., 2010) (Level of Evidence: C).
- CRT may be considered for patients who have LVEF ≤ 35%, sinus rhythm, a non-LBBB pattern with QRS duration 120 to 149 ms, and NYH class III/ambulatory class IV on GDMT (Tang, et al., 2010; Rickard, et al., 2011) (Level of Evidence: B).
- CRT may be considered for patients who have LVEF ≤ 35%, sinus rhythm, a non-LBBB pattern with a QRS duration ≥ 150 ms, and NYHA class II symptoms on GDMT (Moss, et al., 2009; Tang, et al., 2010) (Level of Evidence: B).

Class III: No Benefit

- CRT is not recommended for patients with NYHA class I or II symptoms and non-LBBB pattern with QRS duration less than 150 ms (Moss, et al., 2009; Tang, et al., 2010; Rickard, et al., 2011) (Level of Evidence: B).
- CRT is not indicated for patients whose comorbidities and/or frailty limit survival with good functional capacity to less than 1 year (Moss, et al., 2009) (Level of Evidence: C).

American College of Cardiology Foundation (ACCF)/American Heart Association (AHA) Practice Guideline for the Management of Heart Failure

In 2013, the ACCF/AHA Guideline for the Management of Heart Failure was updated (Yancy, et al., 2013). The CRT recommendations for device therapy for management of Stage C heart failure (i.e., structural heart disease with prior or current symptoms of heart failure) are in complete alignment with recommendations in the 2012 ACCF/AHA/HRS focused update for device-based therapy of cardiac rhythm abnormalities as noted above (Tracy, et al., 2012). The recommendations have not changed in the 2017 focused updated of the ACCF/AHA/HFSA Guideline for the Management of Heart Failure (Yancy, et al., 2017).

Heart Failure Society Indications for Cardiac Resynchronization Therapy

The updated 2011 Heart Failure Society Indications for Cardiac Resynchronization Therapy states that, “After evaluating the totality of evidence and based on the general consistency across clinical trials, the HFSA Guideline Committee determined that CRT is recommended for patients in sinus rhythm with a widened QRS interval (≥ 150 ms) that is not due to right bundle branch block who have severe LV systolic dysfunction (LVEF ≤ 35%) and persistent mild-to-moderate heart failure (NYHA functional class II-III) despite optimal medical therapy. CRT may be considered for ambulatory NYHA functional class IV patients with QRS interval ≥150 ms and severe LV systolic dysfunction (LVEF ≤ 35%). CRT may be considered for patients with a QRS interval of ≥120 to < 150 ms and severe LV systolic dysfunction (LVEF ≤ 35%) who have persistent mild to severe heart failure (NYHA functional class II to ambulatory class IV) despite optimal medical therapy”.

The HFSA uses 4 levels of strength in its guideline recommendations. These include “is recommended,” indicating that the therapy should be part of routine care and exceptions minimized; “should be considered,” indicating that the majority of patients should receive the intervention; “may be considered,” indicating that patient individualization is needed in the application of therapy; and “is not recommended,” indicating that the therapy should not be used (Stevenson, et al., 2012).

American College of Cardiology; American Heart Association Task Force; European Society of Cardiology Committee for Practice Guidelines for Management of Patients with Ventricular Arrhythmias and the Prevention of Sudden Cardiac Death

The 2017 update to the 2006 ACC/AHA/ESC guideline for management of patients with ventricular arrhythmias and the prevention of sudden cardiac death does not include considerations relevant to cardiac resynchronization therapy (CRT) (Al-Khatib, et al., 2017).

Centers for Medicare & Medicaid Services (CMS)

- National Coverage Determinations (NCDs): No NCD found.
Use Outside of the US
St. Jude Medical has CE Mark clearance in Europe for the Quadra Assura MP™ cardiac resynchronization therapy defibrillator allows heart pacing to occur at several locations on the left side of the heart. Quadra Assura MP is an investigational device in the US.

CE Marking was granted for the WiSE CRT System in October 2015. The company anticipates introducing a second-generation WiSE system in Europe. The transmitter size has been reduced by half, making it smaller than a conventional pacemaker. Second-generation battery life is expected to equal conventional CRT systems.

Canadian Cardiovascular Society (CCS)
The 2013 CCS guidelines on the use of cardiac resynchronization therapy: implementation was developed to address the practical use of cardiac resynchronization therapy (CRT), beyond clinical trial inclusion/exclusion criteria, in a real world population (Parkash, et al., 2013). The nine recommendations in the document are based on the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) assessment method and expert consensus.

Quality of evidence and definitions state that when the desirable effects of an intervention clearly outweigh the undesirable effects, or clearly do not, guideline panels offer strong recommendations. On the other hand, when the trade-offs are less certain—either because of low quality evidence or because evidence suggests that desirable and undesirable effects are closely balanced—weak recommendations become mandatory.

Quality of evidence and definitions:

- High quality: Further research is very unlikely to change our confidence in the estimate of effect.
- Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
- Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
- Very low quality: Any estimate of effect is very uncertain.

The following recommendations are in the 2013 guideline:

- Recommend that the prescription of CRT and the choice of platform (CRT-P versus CRT-D) should take into account clinical factors that would affect the overall goals of care (Strong Recommendation, Moderate-Quality Evidence).

- Suggest that CRT might be considered for patients with new-onset high-degree AV block requiring chronic RV pacing, signs and/or symptoms of heart failure, and LVEF ≤45% (Conditional Recommendation, Moderate-Quality Evidence).

- Recommend that all patients with heart failure who are planned to receive a cardiac implantable electronic device system revision should be considered for their eligibility for upgrade to CRT (Strong Recommendation, Low-Quality Evidence).

- Suggest that placement of an LV lead at the time of open heart surgery, for the purpose of facilitating future CRT, might be considered in patients for whom CRT is recommended and the need for device therapy is unlikely to be changed by the surgical procedure ( Conditional Recommendation, Low-Quality Evidence).

- Recommend that in patients taking warfarin for whom perioperative anticoagulation is deemed necessary, continued warfarin is recommended over the use of heparin-based bridging (Strong Recommendation, Moderate-Quality Evidence).
• Recommend that CRT implantation be performed only in facilities that have strict infection prevention control standards (Strong Recommendation, Low-Quality Evidence).

• Recommend that appropriate fluoroscopic equipment, radiation shielding, and radiation reduction imaging methods be used to minimize radiation exposure to the operator, patient, and other staff (Strong Recommendation, Low-Quality Evidence).

• Recommend that alterations in clinical parameters after versus before CRT be assessed within 6 to 12 months after CRT implantation to guide ongoing heart failure management (Strong Recommendation, Low-Quality Evidence).

• Suggest that CRT implantation occur within 6-8 weeks from the decision to implant to avoid preventable adverse events, such as heart failure hospitalizations and death (Conditional Recommendation, Low-Quality Evidence).

European Society of Cardiology (ESC) Guidelines on cardiac pacing and cardiac resynchronization therapy

The following recommendations for CRT placement are included in the 2013 guideline. Guideline recommendations are classified as Class I, Class IIa, Class IIb, and Class III. The classification system is described as follows (Brignole, et al., 2013):

• Class I: Evidence and/or general agreement that a given treatment or procedure is beneficial, useful, effective.
• Class II: Conflicting evidence and/or a divergence of opinion about the usefulness/efficacy of the given treatment or procedure.
• Class IIa: Weight of evidence/opinion is in favour of usefulness/efficacy.
• Class IIb: Usefulness/efficacy is less well established by evidence/opinion.
• Class III: Evidence or general agreement that the given treatment or procedure is not useful/effective, and in some cases may be harmful.

The weight of evidence supporting each recommendation is classified as follows:

• Level A: Data derived from multiple randomized clinical trials or meta-analysis.
• Level B: Data derived from a single randomized clinical trial or large non-randomized clinical trials.
• Level C: Consensus of opinion of the experts and/or small studies, retrospective studies, registries.

Indications for CRT in patients in SR:

• LBBB with QRS duration >150 ms. CRT is recommended in chronic HF patients and LVEF ≤35% who remain in NYHA functional class II, III and ambulatory IV despite adequate medical treatment (Class I, Level A).
• LBBB with QRS duration 120–150 ms. CRT is recommended in chronic HF patients and LVEF ≤35% who remain in NYHA functional class II, III and ambulatory IV despite adequate medical treatment (Class I, Level B).
• Non-LBBB with QRS duration >150 ms. CRT should be considered in chronic HF patients and LVEF ≤35% who remain in NYHA functional class II, III and ambulatory IV despite adequate medical treatment (Class IIa, Level B).
• Non-LBBB with QRS duration 120–150 ms. CRT may be considered in chronic HF patients and LVEF ≤35% who remain in NYHA functional class II, III and ambulatory IV despite adequate medical treatment (Class IIb, Level B).
• CRT in patients with chronic HF with QRS duration <120 ms is not recommended (Class III, Level B).

Indications for CRT in patients with permanent atrial fibrillation:
Patients with HF, wide QRS and reduced LVEF:
- CRT should be considered in chronic HF patients, intrinsic QRS ≥120 ms and LVEF ≤35% who remain in NYHA functional class III and ambulatory IV despite adequate medical treatment, provided that a BiV pacing as close to 100% as possible can be achieved (Class IIa, Level B).
- AV junction ablation should be added in case of incomplete BiV pacing (Class IIa, Level B).

Patients with uncontrolled heart rate who are candidates for AV junction ablation. CRT should be considered in patients with reduced LVEF who are candidates for AV junction ablation for rate control (Class IIa, Level B).

European Society of Cardiology (ESC) Guidelines for the Diagnosis and Treatment of Acute and Chronic Heart Failure
In 2016, the 2012 ESC guidelines for the diagnosis and treatment of acute and chronic heart failure were updated. The ESC guideline has the following updated recommendations for CRT (Ponikowski, et al., 2016; McMurray, et al., 2012).

- CRT is recommended for symptomatic patients with HF in sinus rhythm with a QRS duration ≥150 msec and LBBB QRS morphology and with LVEF ≤35% despite OMT in order to improve symptoms and reduce morbidity and mortality. (Class I, Level A)
- CRT should be considered for symptomatic patients with HF in sinus rhythm with a QRS duration ≥150 msec and non-LBBB QRS morphology and with LVEF ≤35% despite optimal medical therapy (OMT) in order to improve symptoms and reduce morbidity and mortality. (Class IIa, Level B)
- CRT is recommended for symptomatic patients with HF in sinus rhythm with a QRS duration of 130–149 msec and LBBB QRS morphology and with LVEF ≤35% despite OMT in order to improve symptoms and reduce morbidity and mortality. (Class I, Level B)
- CRT may be considered for symptomatic patients with HF in sinus rhythm with a QRS duration of 130–149 msec and non-LBBB QRS morphology and with LVEF ≤35% despite OMT in order to improve symptoms and reduce morbidity and mortality. (Class IIb, Level B)
- CRT rather than RV pacing is recommended for patients with heart failure with reduced ejection fraction (HFrEF) regardless of NYHA class who have an indication for ventricular pacing and high degree AV block in order to reduce morbidity. This includes patients with AF (see Section 10.1). (Class I, Level A)
- CRT should be considered for patients with LVEF ≤35% in NYHA Class III–IV despite OMT in order to improve symptoms and reduce morbidity and mortality, if they are in AF and have a QRS duration ≥130 msec provided a strategy to ensure bi-ventricular capture is in place or the patient is expected to return to sinus rhythm. (Class IIa, Level B)
- Patients with HFrEF who have received a conventional pacemaker or an ICD and subsequently develop worsening HF despite OMT and who have a high proportion of RV pacing may be considered for upgrade to CRT. This does not apply to patients with stable HF. (Class IIb, Level B)
- CRT is contraindicated in patients with a QRS duration < 130 msec. (Class III, Level A)

European Society of Cardiology (ESC) Guidelines on Device Therapy in Heart Failure
The 2010 focused update of ESC guidelines on device therapy in heart failure (Dickstein, et al., 2010) have the following recommendations for cardiac resynchronization therapy:

Recommendation in patients with heart failure in NYHA class III/IV:

- CRT-P/CRT-D is recommended to reduce morbidity and mortality for: NYHA class III/IV, LVEF ≤35%, QRS ≥120 ms, SR, optimal medical therapy, class IV patients should be ambulatory (Class I, Level A).

Recommendation in patients with heart failure in New York Heart Association function class II:
CRT preferentially by CRT-D is recommended to reduce morbidity or to prevent disease progression for: NYHA function class II, LVEF ≤35%, QRS ≥150 ms, SR, optimal medical therapy (Class I, Level A).

Recommendations in patients with heart failure and permanent atrial fibrillation:

- CRT-P/CRT-D should be considered to reduce morbidity for:
  - NYHA class III/IV, LVEF ≤ 35%, QRS ≥ 130 ms, pacemaker dependency induced by AV nodal ablation (Class IIa, Level B).
  - NYHA class III/IV, LVEF ≤ 35%, QRS ≥ 130 ms, slow ventricular rate and frequent pacing (i.e., ≥ 95% pacemaker dependence. (Class IIa, Level C).

Recommendations in patients with heart failure and a concomitant class I pacemaker indication:

- CRT-P/CRT-D is recommended to reduce morbidity for:
  - NYHA class III/IV, LVEF ≤35%, QRS ≥120 ms (Class I, Level B).
  - NYHA class III/IV, LVEF ≤35%, QRS <120 ms (Class IIa, Level C).
  - NYHA class II, LVEF ≤35%, QRS <120 ms (Class IIb, Level C).

**Appendix A**

The New York Heart Association (NYHA) classification of heart failure is a 4-tier system that categorizes patients based on subjective impression of the degree of functional compromise. The chart below defines the four NYHA functional classes. Advanced heart failure is categorized as NYHA Class III and Class IV.

<table>
<thead>
<tr>
<th>Class I:</th>
<th>patients with cardiac disease but without resulting limitation of physical activity; ordinary physical activity does not cause undue fatigue, palpitation, dyspnea or anginal pain; symptoms only occur on severe exertion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class II:</td>
<td>patients with cardiac disease resulting in slight limitation of physical activity; they are comfortable at rest; ordinary physical activity results in fatigue, palpitation, dyspnea or anginal pain</td>
</tr>
<tr>
<td>Class III:</td>
<td>patients with cardiac disease resulting in marked limitation of physical activity; they are comfortable at rest; less than ordinary activity (e.g., mild exertion) causes fatigue, palpitation, dyspnea or anginal pain</td>
</tr>
<tr>
<td>Class IV:</td>
<td>patients with cardiac disease resulting in inability to carry on any physical activity without discomfort; symptoms of cardiac insufficiency or anginal syndrome is present at rest; if any physical activity is undertaken, discomfort is increased</td>
</tr>
</tbody>
</table>

**Coding/Billing Information**

**Note:**
1) This list of codes may not be all-inclusive.
2) Deleted codes and codes which are not effective at the time the service is rendered may not be eligible for reimbursement.

**Considered Medically Necessary when used to report the insertion or replacement of a biventricular pacemaker or when combined with an implantable cardioverter defibrillator and/or leads:**

<table>
<thead>
<tr>
<th>CPT® Codes</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>33202</td>
<td>Insertion of epicardial electrode(s); open incision (eg, thoracotomy, median sternotomy, subxiphoid approach)</td>
</tr>
<tr>
<td>33203</td>
<td>Insertion of epicardial electrode(s); endoscopic approach (eg, thoracoscopy,</td>
</tr>
</tbody>
</table>

Medical Coverage Policy: 0174
<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>33207</td>
<td>Insertion of new or replacement of permanent pacemaker with transvenous electrode(s); ventricular</td>
</tr>
<tr>
<td>33208</td>
<td>Insertion of new or replacement of permanent pacemaker with transvenous electrode(s); atrial and ventricular</td>
</tr>
<tr>
<td>33211</td>
<td>Insertion or replacement of temporary transvenous dual chamber pacing electrodes (separate procedure)</td>
</tr>
<tr>
<td>33213</td>
<td>Insertion of pacemaker pulse generator only; with existing dual leads</td>
</tr>
<tr>
<td>33214</td>
<td>Upgrade of implanted pacemaker system, conversion of single chamber system to dual chamber system (includes removal of previously placed pulse generator, testing of existing lead, insertion of new lead, insertion of new pulse generator)</td>
</tr>
<tr>
<td>33217</td>
<td>Insertion of 2 transvenous electrodes, permanent pacemaker or implantable defibrillator</td>
</tr>
<tr>
<td>33221</td>
<td>Insertion of pacemaker pulse generator only; with existing multiple leads</td>
</tr>
<tr>
<td>33222</td>
<td>Relocation of skin pocket for pacemaker</td>
</tr>
<tr>
<td>33224</td>
<td>Insertion of pacing electrode, cardiac venous system, for left ventricular pacing, with attachment to previously placed pacemaker or implantable defibrillator pulse generator (including revision of pocket, removal, insertion, and/or replacement of existing generator)</td>
</tr>
<tr>
<td>33225</td>
<td>Insertion of pacing electrode, cardiac venous system, for left ventricular pacing, at time of insertion of implantable defibrillator or pacemaker pulse generator (eg, for upgrade to dual chamber system) (List separately in addition to code for primary procedure)</td>
</tr>
<tr>
<td>33226</td>
<td>Repositioning of previously implanted cardiac venous system (left ventricular) electrode (including removal, insertion and/or replacement of existing generator)</td>
</tr>
<tr>
<td>33228</td>
<td>Removal of permanent pacemaker pulse generator with replacement of pacemaker pulse generator; dual lead system</td>
</tr>
<tr>
<td>33229</td>
<td>Removal of permanent pacemaker pulse generator with replacement of pacemaker pulse generator; multiple lead system</td>
</tr>
<tr>
<td>33230</td>
<td>Insertion of implantable defibrillator pulse generator only; with existing dual leads</td>
</tr>
<tr>
<td>33231</td>
<td>Insertion of implantable defibrillator pulse generator only; with existing multiple leads</td>
</tr>
<tr>
<td>33240</td>
<td>Insertion implantable defibrillator pulse generator only; with existing single lead</td>
</tr>
<tr>
<td>33249</td>
<td>Insertion or replacement of permanent implantable defibrillator system, with transvenous lead(s), single or dual chamber</td>
</tr>
<tr>
<td>33263</td>
<td>Removal of implantable defibrillator pulse generator with replacement of implantable defibrillator pulse generator; dual lead system</td>
</tr>
<tr>
<td>33264</td>
<td>Removal of implantable defibrillator pulse generator with replacement of implantable defibrillator pulse generator; multiple lead system</td>
</tr>
</tbody>
</table>

### HCPCS Codes

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1721</td>
<td>Cardioverter-defibrillator, dual chamber (implantable)</td>
</tr>
<tr>
<td>C1722</td>
<td>Cardioverter-defibrillator, single chamber (implantable)</td>
</tr>
<tr>
<td>C1777</td>
<td>Lead, cardioverter-defibrillator, endocardial single coil (implantable)</td>
</tr>
<tr>
<td>C1779</td>
<td>Lead, pacemaker, transvenous VDD single pass</td>
</tr>
<tr>
<td>C1785</td>
<td>Pacemaker, dual chamber, rate-responsive (implantable)</td>
</tr>
<tr>
<td>C1786</td>
<td>Pacemaker, single chamber, rate-responsive (implantable)</td>
</tr>
<tr>
<td>C1882</td>
<td>Cardioverter-defibrillator, other than single or dual chamber (implantable)</td>
</tr>
<tr>
<td>C1895</td>
<td>Lead, cardioverter-defibrillator, endocardial dual coil (implantable)</td>
</tr>
<tr>
<td>C1896</td>
<td>Lead, cardioverter-defibrillator, other than endocardial single or dual coil</td>
</tr>
<tr>
<td>C1898</td>
<td>Lead, pacemaker, other than transvenous VDD single pass</td>
</tr>
<tr>
<td>C1899</td>
<td>Lead, pacemaker/cardioverter-defibrillator combination (implantable)</td>
</tr>
<tr>
<td>C1900</td>
<td>Lead, left ventricular coronary venous system</td>
</tr>
<tr>
<td>C2619</td>
<td>Pacemaker, dual chamber, non rate-responsive (implantable)</td>
</tr>
<tr>
<td>C2620</td>
<td>Pacemaker, single chamber, non rate-responsive (implantable)</td>
</tr>
<tr>
<td>C2621</td>
<td>Pacemaker, other than single or dual chamber (implantable)</td>
</tr>
<tr>
<td>G0448</td>
<td>Insertion or replacement of a permanent pacing cardioverter-defibrillator system with</td>
</tr>
</tbody>
</table>
transvenous lead(s), single or dual chamber with insertion of pacing electrode, cardiac venous system, for left ventricular pacing

Considered Experimental/Investigational/Unproven:

<table>
<thead>
<tr>
<th>CPT®® Codes</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>33999†</td>
<td>Unlisted procedure, cardiac surgery</td>
</tr>
<tr>
<td>0515T</td>
<td>Insertion of wireless cardiac stimulator for left ventricular pacing, including device interrogation and programming, and imaging supervision and interpretation, when performed; complete system (includes electrode and generator [transmitter and battery])</td>
</tr>
<tr>
<td>0516T</td>
<td>Insertion of wireless cardiac stimulator for left ventricular pacing, including device interrogation and programming, and imaging supervision and interpretation, when performed; electrode only</td>
</tr>
<tr>
<td>0517T</td>
<td>Insertion of wireless cardiac stimulator for left ventricular pacing, including device interrogation and programming, and imaging supervision and interpretation, when performed; pulse generator component(s) (battery and/or transmitter) only</td>
</tr>
<tr>
<td>0518T</td>
<td>Removal of only pulse generator component(s) (battery and/or transmitter) of wireless cardiac stimulator for left ventricular pacing</td>
</tr>
<tr>
<td>0519T</td>
<td>Removal and replacement of wireless cardiac stimulator for left ventricular pacing; pulse generator component(s) (battery and/or transmitter)</td>
</tr>
<tr>
<td>0520T</td>
<td>Removal and replacement of wireless cardiac stimulator for left ventricular pacing; pulse generator component(s) (battery and/or transmitter), including placement of a new electrode</td>
</tr>
<tr>
<td>0521T</td>
<td>Interrogation device evaluation (in person) with analysis, review and report, includes connection, recording, and disconnection per patient encounter, wireless cardiac stimulator for left ventricular pacing</td>
</tr>
<tr>
<td>0522T</td>
<td>Programming device evaluation (in person) with iterative adjustment of the implantable device to test the function of the device and select optimal permanent programmed values with analysis, including review and report, wireless cardiac stimulator for left ventricular pacing</td>
</tr>
</tbody>
</table>

†Note: Considered Experimental/Investigational/Unproven when used to report His bundle pacing (HBP) for any indication


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