Biventricular Pacemakers (Cardiac Resynchronization Therapy) for the Treatment of Heart Failure

Policy Number: 2.02.10  Last Review: 8/2018

Policy

Blue Cross and Blue Shield of Kansas City (Blue KC) will provide coverage for biventricular pacemakers for the treatment of congestive heart failure when it is determined to be medically necessary because the criteria shown below are met.

When Policy Topic is covered

Biventricular pacemakers with or without an accompanying implantable cardiac defibrillator (i.e. a combined biventricular pacemaker/ICD) may be considered medically necessary as a treatment of heart failure in patients who meet all of the following criteria:

New York Heart Association Class III or IV
- Left ventricular ejection fraction ≤35%
- Sinus rhythm
- Patients treated with guideline-directed medical therapy (see Considerations section)

AND
- Either left bundle branch block OR QRS duration ≥150 ms

New York Heart Association class II
- Left ventricular ejection fraction ≤30%
- Sinus rhythm
- Patients treated with a guideline-directed medical therapy (see Considerations section)

AND
- Either left bundle branch block OR QRS duration ≥150 ms

For patients who do not meet the criteria outlined above, but who have an indication for a ventricular pacemaker, biventricular pacemakers with or without an accompanying implantable cardiac defibrillator (ie, a combined biventricular
pacemaker/ICD) may be considered medically necessary as an alternative to a right ventricular pacemaker in patients who meet all of the following criteria:

- NYHA class I, II, III, or IV heart failure;
- Left ventricular ejection fraction ≤50%;
- The presence of atrioventricular (AV) block with requirement for a high percentage of ventricular pacing (see Considerations section); and
- Patients treated with guideline-directed medical therapy (see Considerations section)

**When Policy Topic is not covered**

Biventricular pacemakers, with or without an accompanying implantable cardiac defibrillator (i.e., a combined biventricular pacemaker/ICD) are considered investigational as a treatment for patients with NYHA class I heart failure who do not meet the above criteria.

Biventricular pacemakers, with or without an accompanying implantable cardiac defibrillator (i.e., a combined biventricular pacemaker/ICD), are considered investigational as a treatment for heart failure in patients with atrial fibrillation who do not meet the above criteria.

An intrathoracic fluid monitoring sensor is considered investigational as a component of a biventricular pacemaker.

Triple-site (triventricular) CRT, using an additional pacing lead, is considered investigational.

Cardiac resynchronization therapy with wireless left ventricular endocardial pacing is considered investigational.

**Considerations**

**Policy Definitions**

AV block with a requirement for a high percentage of ventricular pacing is considered to be present when there is either:

- 3rd degree AV block; or
- 2nd degree AV block or a PR interval of 300 ms or more when paced at 100 beats per minute.

Guideline-directed medical therapy for heart failure is outlined in 2013 American College of Cardiology Foundation/American Heart Association guidelines for the management of heart failure.

**Coding Issues**

Note that CPT “dual chamber” codes describe combined right atrial and right ventricular electrode placement. CPT “biventricular” codes describe the additional placement of a left ventricular electrode via the cardiac vein. A left ventricular pacing lead is placed in the marginal branch of the coronary sinus and into a
cardiac vein to allow for biventricular pacing for cardiac resynchronization. CPT notes the following:

“A single chamber pacemaker system includes a pulse generator and 1 electrode inserted in either the atrium or the ventricle. A dual chamber pacemaker system includes a pulse generator and 1 electrode inserted in the right atrium and 1 electrode inserted in the right ventricle. In certain circumstances, an additional electrode may be required to achieve pacing of the left ventricle (biventricular pacing). In this event, transvenous (cardiac vein) placement of the electrode should be separately reported using code 33224 or 33225. Epicardial placement of the electrode should be separately reported using 33202-33203.”

- 33224 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).
- 33225 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 procedures).

Use 33225 in conjunction with 33206, 33207, 33208, 33212, 33213, 33214, 33216, 33217, 33221, 33223, 33228, 33229, 33230, 33231, 33233, 33234, 33235, 33240, 33249, 33263, and 33264.

Thus, CPT describes 33225 as an “add-on” code to other pacing or implantable defibrillator procedures.

### Description of Procedure or Service

<table>
<thead>
<tr>
<th>Populations</th>
<th>Interventions of interest are:</th>
<th>Comparators of interest are:</th>
<th>Relevant outcomes include:</th>
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<tbody>
<tr>
<td>Individuals:</td>
<td>Cardiac resynchronization therapy with or without defibrillator</td>
<td>Medical care and Medical care plus defibrillator</td>
<td>Overall survival, Symptoms, Functional outcomes, Quality of life, Hospitalizations, Treatment-related morbidity</td>
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<tr>
<td>With New York Heart Association class III or IV heart failure</td>
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<tbody>
<tr>
<td>With New York Heart Association class II heart failure</td>
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</table>
### Biventricular Pacemakers (Cardiac Resynchronization Therapy) for the Treatment of Heart Failure 2.02.10

<table>
<thead>
<tr>
<th>Heart Association class I heart failure</th>
<th>Interventions of interest are:</th>
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<td>Medical care plus defibrillator</td>
<td>Overall survival</td>
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<td>Medical care plus defibrillator</td>
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<td>Medical care</td>
<td>Symptoms</td>
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<td>Medical care</td>
<td>Medical care plus defibrillator</td>
<td>Medical care plus defibrillator</td>
<td>Functional outcomes</td>
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<td>Medical care</td>
<td>Medical care plus defibrillator</td>
<td>Medical care plus defibrillator</td>
<td>Quality of life</td>
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<td>Cardiac resynchronization therapy with or without defibrillator</td>
<td>Medical care plus defibrillator</td>
<td>Medical care plus defibrillator</td>
<td>Hospitalizations</td>
</tr>
<tr>
<td>Medical care plus defibrillator</td>
<td>Medical care plus defibrillator</td>
<td>Medical care plus defibrillator</td>
<td>Treatment-related morbidity</td>
</tr>
</tbody>
</table>

### Individuals:
- **With heart failure and atrial fibrillation**

### Interventions of interest are:
- Cardiac resynchronization therapy with or without defibrillator

### Comparators of interest are:
- Medical care
- Medical care plus defibrillator

### Relevant outcomes include:
- Overall survival
- Symptoms
- Functional outcomes
- Quality of life
- Hospitalizations
- Treatment-related morbidity

### Individuals:
- **With heart failure and atrioventricular nodal block**

### Interventions of interest are:
- Cardiac resynchronization therapy

### Comparators of interest are:
- Medical care
- Medical care plus defibrillator

### Relevant outcomes include:
- Overall survival
- Symptoms
- Functional outcomes
- Quality of life
- Hospitalizations
- Treatment-related morbidity

### Individuals:
- **With heart failure**

### Interventions of interest are:
- Triple-site cardiac resynchronization therapy

### Comparators of interest are:
- Standard cardiac resynchronization therapy

### Relevant outcomes include:
- Overall survival
- Symptoms
- Functional outcomes
- Quality of life
- Hospitalizations
- Treatment-related morbidity

### Individuals:
- **With heart failure**

### Interventions of interest are:
- Cardiac resynchronization therapy combined with remote fluid monitoring

### Comparators of interest are:
- Standard cardiac resynchronization therapy only

### Relevant outcomes include:
- Overall survival
- Symptoms
- Functional outcomes
- Quality of life
- Hospitalizations
- Treatment-related morbidity

Cardiac resynchronization therapy (CRT), which consists of synchronized pacing of the left and right ventricles, is intended to treat patients with heart failure and dyssynchronous ventricular contractions. Treatment involves placement of a device that paces both ventricles and which coordinates ventricular pacing to maximize cardiac pumping function and left ventricular ejection fraction (LVEF).

For individuals who have advanced heart failure (New York Heart Association [NYHA] class III/IV) who receive CRT, the evidence includes randomized controlled trials (RCTs) and systematic reviews of RCTs. Relevant outcomes are overall survival, symptoms, functional outcomes, quality of life, hospitalizations, and treatment-related morbidity. There is a large body of clinical trial evidence.
supporting use of CRT in patients with NYHA class III or IV heart failure. The RCTs have consistently reported that CRT treatment reduces mortality, improves functional status, and improves quality of life for patients with NYHA class III or IV heart failure. Multiple subgroup analyses of RCTs have demonstrated that the benefit of CRT is mainly restricted to patients with left bundle branch block (LBBB) or QRS duration greater than 150 ms. The evidence is sufficient to determine quantitatively that the technology results in a meaningful improvement in the net health outcome.

For individuals who have mild heart failure (New York Heart Association class I/II) who receive CRT, the evidence includes RCTs and systematic reviews of RCTs. Relevant outcomes are overall survival, symptoms, functional outcomes, quality of life, hospitalizations, and treatment-related morbidity. For patients with mild heart failure (NYHA class I/II), at least 4 RCTs of CRT have been published. A mortality benefit was reported in 1 of the 4 trials, the RAFT trial. None of the other 3 RCTs reported a mortality difference, but a subgroup analysis of the MADIT-CRT trial reported a mortality benefit for patients with LBBB. Among other outcome measures, hospitalizations for heart failure showed consistent improvements, but quality of life and functional status did not. Multiple subgroup analyses of RCTs have demonstrated that the benefit of CRT is mainly restricted to patients with LBBB or QRS duration greater than 150 ms. The evidence is sufficient to determine qualitatively that the technology results in a meaningful improvement in the net health outcome.

For individuals who have NYHA class I heart failure who receive CRT with or without defibrillator, the evidence includes RCTs and systematic reviews of RCTs. Relevant outcomes are overall survival, symptoms, functional outcomes, quality of life, hospitalizations, and treatment-related morbidity. Few patients with NYHA class I heart failure have been included in RCTs. The MADIT-CRT trial included 265 patients with class I. While the treatment effect on death and hospitalization favored combined implantable cardiac defibrillator (ICD) plus CRT devices versus ICD alone for class I patients, the confidence interval was large and included a 25% to 30% increase in events. The evidence is insufficient to determine the effects of the technology on health outcomes.

For individuals who have heart failure and atrial fibrillation who receive CRT with or without defibrillator, the evidence includes 4 RCTs and observational studies. Relevant outcomes are overall survival, symptoms, functional outcomes, quality of life, hospitalizations, and treatment-related morbidity. Data from RCTs have reported conflicting results, with 1 reporting improvements for patients with atrial fibrillation and others reporting no significant improvements. Results from observational studies are also conflicting. The evidence is insufficient to determine the effects of the technology on health outcomes.

For individuals who have heart failure and atrioventricular (AV) nodal block who receive CRT, the evidence includes RCTs and systematic reviews of RCTs. Relevant outcomes are overall survival, symptoms, functional outcomes, quality of life, hospitalizations, and treatment-related morbidity. One large RCT demonstrated
that CRT led to improvements in heart failure–related hospitalizations and urgent care visits among patients with heart failure and AV block but who would not necessarily meet conventional criteria for CRT. For patients who require ventricular pacing but have no left ventricular dysfunction, results of 1 small RCT have suggested that biventricular pacing is associated with improved measures of cardiac function, but the trial was small and underpowered to detect differences in clinical outcomes. The evidence is sufficient to determine that the technology results in a meaningful improvement in the net health outcome.

For individuals who have heart failure who receive triple-site CRT, the evidence includes small RCTs. Relevant outcomes are overall survival, symptoms, functional outcomes, quality of life, hospitalizations, and treatment-related morbidity. The available RCTs have reported improved outcomes on at least 1 measure of functional status or quality of life with triple-site CRT compared to conventional CRT. However, the trials are small and have methodologic limitations. In addition, outcomes reported differed across studies. Triple-site CRT was also associated with higher radiation exposure and a greater number of additional procedures postimplantation. Larger, high-quality RCTs are needed to better define the benefit-risk ratio for triple-site CRT compared to conventional CRT. The evidence is insufficient to determine the effects of the technology on health outcomes.

For individuals who have heart failure who receive CRT combined with remote fluid monitoring, the evidence includes 3 RCTs. Relevant outcomes are overall survival, symptoms, functional outcomes, quality of life, hospitalizations, and treatment-related morbidity. Three RCTs have reported no improvement in outcomes associated with remote fluid monitoring for patients with heart failure. The evidence is insufficient to determine the effects of the technology on health outcomes.

**Background**

It is estimated that 20% to 30% of patients with heart failure have intraventricular conduction disorders, resulting in a contraction pattern that is not coordinated and a wide QRS interval on the electrocardiogram. This abnormality appears to be associated with increased morbidity and mortality.

Biventricular pacemakers using 3 leads (1 in the right atrium, 1 in each ventricle), also known as CRT, have been investigated as a technique to coordinate the contraction of the ventricles, thus improving patients’ hemodynamic status. Several types of CRT devices are available, including those that incorporate biventricular pacing into automatic implantable cardiac defibrillators (ICDs), stand-alone biventricular pacemakers, and biventricular pacemakers that incorporate fluid monitoring via bioimpedance.

Originally developed CRT devices typically used 2 ventricular leads for biventricular pacing. Devices and implantation techniques have been developed to allow for multisite pacing, with the goal of improving CRT response. This may be accomplished in 1 of 2 ways: through the use of multiple leads within the coronary
sinus (triventricular pacing) or through the use of multipolar left ventricular pacing leads, which can deliver pacing stimuli at multiple sites.

**Regulatory Status**

There are numerous cardiac resynchronization therapy (CRT) devices, combined implantable cardiac defibrillator (ICD) plus CRT devices (CRT-D), and combined CRT plus fluid monitoring devices. Some devices are discussed here. For example, in 2001, the InSync® Biventricular Pacing System (Medtronic), a stand-alone biventricular pacemaker, was approved by the U.S. Food and Drug Administration (FDA) through the premarket approval process for the treatment of patients with New York Heart Association (NYHA) class III or IV heart failure, on a stable pharmacologic regimen, who also have a QRS duration of 130 ms or longer and a left ventricular ejection fraction (LVEF) of 35% or less. Devices by Guidant (CONTAK CD® CRT-D System) and Medtronic (InSync® ICD Model 7272) have been approved by FDA through the premarket approval process for combined cardiac resynchronization therapy defibrillators for patients at high risk of sudden cardiac death due to ventricular arrhythmias and who have NYHA class III or IV heart failure with LVEF of 35% or less, QRS duration 130 ms or longer (≥120 ms for the Guidant device), and remain symptomatic despite a stable, optimal heart failure drug therapy. In 2006, Biotronik Inc. received premarket approval from FDA for its combined ICD-CRT device with ventricular pacing leads (Tupos LV/ATx CRT-D/Kronos LV-T CRT-D systems); in 2013, the company received FDA approval for updated ICD-CRT devices (Ilesto/Iforia series).

In September 2010, FDA expanded the indications for some CRT devices to include patients with class I and II heart failure. Based on data from the MADIT-CRT study, indications for 3 Guidant (Boston Scientific) CRT-defibrillator devices (Cognis®, Livian®, and Contak Renewal devices) were expanded to include patients with heart failure who receive stable optimal pharmacologic therapy for heart failure and who meet any one of the following classifications:

- Moderate-to-severe heart failure (NYHA class III-IV) with ejection fraction less than 35% and QRS duration greater than 120 ms.
- Left bundle branch block with QRS greater than or equal to 130 ms, ejection fraction less than 30%, and mild (NYHA class II) ischemic or nonischemic heart failure or asymptomatic (NYHA class I) ischemic heart failure.

In April 2014, FDA further expanded the indications for multiple Medtronic CRT devices to include patients with NYHA functional class I, II, or III heart failure, who have LVEF of 50% or less on stable, optimal heart failure medical therapy, if indicated, and have AV block that is expected to require a high percentage of ventricular pacing that cannot be managed with algorithms to minimize right ventricular pacing. The expanded indication was based on data from the BLOCK-HF study, a Medtronic-sponsored RCT to evaluate the use of CRT in patients with NYHA class I, II, or III heart failure, LVEF ≤50%, and AV block.

Several CRT devices incorporate a fourth lead, providing quadripolar pacing. The Medtronic Viva™ Quad XT and the Viva Quad S incorporate a fourth lead, the
Medtronic Attain Performa® left ventricular lead, which received clearance for marketing from FDA in August 2014. The Dynagen™ X4 and Inogen™ X4 devices (Boston Scientific, Marlborough, MA) incorporate a fourth lead. Other CRT devices with quadripolar leads have been approved for use outside of the United States (eg, St. Jude Quartet™ left ventricular lead).

Multiple devices manufactured by Medtronic combine a CRT with the OptiVol™ monitoring system. For example, in 2005, the InSync Sentry® system was approved by FDA through the supplemental premarket approval process. This combined biventricular pacemaker plus ICD is also equipped to monitor intrathoracic fluid levels using bioimpedance technology, referred to as OptiVol™ Fluid Status Monitoring. Bioimpedance measures, defined as the electrical resistance of tissue to flow of current, are performed many times a day using a vector from the right ventricular coil on the lead in the right side of the heart to the implanted pacemaker devices; changes in bioimpedance reflect intrathoracic fluid status and are evaluated using a computer algorithm. For example, changes in a patient’s daily average of intrathoracic bioimpedance can be monitored; differences in the daily average are compared with a baseline and reported as the OptiVol™ Fluid Index. It has been proposed that these data may be used as an early warning system of cardiac decompensation or may provide feedback that enables a physician to tailor medical therapy. Evidence review 2.02.24 addresses the use of external bioimpedance devices as stand-alone devices to assess cardiac output noninvasively.

The WiSE-CRT (EBR Systems) provides CRT with a small wireless electrode that is implanted within the left ventricle and controlled by ultrasound. It has European CE approval and is being studied in a multicenter pivotal trial.

Rationale
This evidence review was created in July 1999 and has been updated regularly with searches of the MEDLINE database. The most recent literature update was performed through March 5, 2018.

Evidence reviews assess the clinical evidence to determine whether the use of a technology improves the net health outcome. Broadly defined, health outcomes are length of life, quality of life, and ability to function—including benefits and harms. Every clinical condition has specific outcomes that are important to patients and to managing the course of that condition. Validated outcome measures are necessary to ascertain whether a condition improves or worsens; and whether the magnitude of that change is clinically significant. The net health outcome is a balance of benefits and harms.

To assess whether the evidence is sufficient to draw conclusions about the net health outcome of a technology, 2 domains are examined: the relevance and the quality and credibility. To be relevant, studies must represent one or more intended clinical use of the technology in the intended population and compare an effective and appropriate alternative at a comparable intensity. For some conditions, the alternative will be supportive care or surveillance. The quality and
credibility of the evidence depend on study design and conduct, minimizing bias 
and confounding that can generate incorrect findings. The randomized controlled 
trial (RCT) is preferred to assess efficacy; however, in some circumstances, 
nonrandomized studies may be adequate. RCTs are rarely large enough or long 
enough to capture less common adverse events and long-term effects. Other types 
of studies can be used for these purposes and to assess generalizability to broader 
clinical populations and settings of clinical practice.

**Cardiac Resynchronization Therapy for Heart Failure**

**Systematic Reviews**

Use of biventricular pacemakers with or without an accompanying implantable 
cardiac defibrillator (ICD) for select patients with advanced heart failure is 
supported by a large body of clinical trial evidence. At least 13 systematic reviews 
have consistently found benefit for cardiac resynchronization therapy (CRT) vs 
comparators for all-cause mortality and heart failure–related hospitalizations.4-16

The 5 systematic reviews published after 2010 that include meta-analyses with 
comparisons of CRT plus ICD (CRT-D) vs ICD alone and/or CRT vs drug therapy 
are shown in Table 1 and AMSTAR (A MeaSurement Tool to Assess systematic 
Reviews) quality ratings are shown in Table 2.

Trial characteristics can be found in the following section in Table 3. The majority 
of patients included in RCTs had New York Heart Association (NYHA) functional 
class II or III with a left ventricular ejection fraction (LVEF) of less than 35%, 
prolonged QRS interval (≥120 ms), and in sinus rhythm. On average, about 75% 
of participants were men, although the percentages of men ranged from 46% to 
100%. Just over half of participants included had ischemic heart disease. The 
systematic reviews consistently reported a 15% to 20% reduction in mortality with 
CRT-D vs ICD alone and a 25% reduction in mortality of CRT vs drug therapy. 
Reviews providing results stratified by NYHA class I or II vs NYHA class III or IV 
have shown significant effects on mortality in both groups, although few patients 
in class I were enrolled in RCTs. The individual patient data network meta-analysis 
by Woods et al (2015) included 12,638 patients and reported a larger reduction in 
mortality (≥40%) for CRT vs drug therapy compared with the other systematic 
reviews.14 The meta-analysis by Sun et al (2016) demonstrated that effects on 
mortality persist when only pooling trials with more than 1 year of follow-up.15

**Randomized Controlled Trials**

At least 30 RCTs have evaluated CRT have been published and are included in at 
least one of the meta-analyses listed above.17-46 Table 3 shows the baseline 
characteristics of the RCTs. The 2 largest RCTs (MADIT-CRT, RAFT) are described 
below.
Table 1. Systematic Reviews of RCTs Assessing the Efficacy of CRT for the Treatment of Heart Failure

<table>
<thead>
<tr>
<th>Study</th>
<th>Dates</th>
<th>Population</th>
<th>Interventions</th>
<th>Studies (N)</th>
<th>Trials Included</th>
<th>Results</th>
</tr>
</thead>
</table>
| Sun et al (2016)  | Through 2015        | NYHA class I/II                    | ▪ CRT-D  
▪ ICD alone            | 3 RCTs (N=3858) with ≥12-mo follow-up | REVERSE, MADIT-CRT, RAFT        | CRT-D vs ICD  
Heart failure hospitalizations  
OR=0.67 (95% CI, 0.50 to 0.89)  
Mortality  
OR=0.78 (95% CI, 0.63 to 0.96) |
| Woods et al (2015) | 1990-2015           | LVEF ≤40%                          | ▪ CRT or CRT-D  
▪ Drug therapy alone or ICD alone | 13 RCTs (N=12,638) | CARE-HF, MIRACLE, REVERSE, MUSTIC-SR, RESPONSE, VECTOR, COMPANION, CONTAK-CD, MADIT-CRT, RAFT, RETHinQ, REVERSE CRT, Piccirillo (2006), Pinter (2009), RHYTHM-ICD, DEFINITEa, MADITa, MADIT IIa, SCD HeFTa, AMIOVIRTa, CATa | CRT-D vs drug therapy  
Mortality  
HR=0.58 (95% CrI, 0.50 to 0.68)  
CRT-D vs ICD  
▪ Mortality  
HR=0.82 (95% CrI, 0.72 to 0.93) |
| Chen et al (2013) | Through 2012        | LVEF ≤35%; QRS interval ≥120 ms    | ▪ CRT-D  
▪ ICD alone            | 8 RCTs (N=5674) | Lozano (2000), CONTAK-CD, MIRACLE-ICD, MIRACLE-ICD II, RHYTHM-ICD, REVERSE, MADIT-CRT, RAFT | CRT-D vs ICD  
Hospitalization  
OR=0.70 (95% CI, 0.60 to 0.81)  
Mortality  
OR=0.80 (95% CI, 0.67 to 0.95) |
| Wells et al (2011)| 1980-2010           | QRS interval ≥120 ms               | ▪ CRT or CRT-D  
▪ ICD alone or drug therapy alone | 12 RCTs (N=7538) | Lozano (2000), MUSTIC, MIRACLE, MIRACLE-ICD, MIRACLE-ICD II, COMPANION, RHYTHM-ICD, CARE-HF, VECTOR, REVERSE, MADIT-CRT, RAFT | CRT vs no CRT  
Mortality  
RR=0.78 (95% CI, 0.70 to 0.87)  
CRT vs drug therapy  
Mortality  
RR=0.73 (95% CI 0.62 to 0.85)  
CRT-D vs ICD  
Mortality |
Bertoldi et al (2011)\textsuperscript{8} LV systolic dysfunction • CRT or CRT-D • ICD alone 12 RCTs (N=8284) MUSTIC-SR, MUSTIC-AF, MIRCACLE, CONTAK-CD, MIRACLE-ICD, MIRACLE-ICD II, COMPANION, CARE-HF, HOBIPLACE, REVERSE, MADIT-CRT, RAFT CRT vs CRT-D vs ICD alone Mortality • RR=0.83 (95% CI, 0.72 to 0.96)

CI: confidence interval; CrI: credible interval; CRT: cardiac resynchronization therapy; CRT-D: cardiac resynchronization therapy with implantable cardioverter defibrillator; HR: hazard ratio; ICD: implantable cardioverter defibrillator; LV: left ventricular; LVEF: left ventricular ejection fraction; NYHA: New York Heart Association; OR: odds ratio; RCT: randomized controlled trial; RR: relative risk.

\textsuperscript{a}Trials of ICD vs medical therapy; used in the indirect comparisons in the network meta-analysis.

Table 2. AMSTAR Quality of Systematic Reviews of Cardiac Resynchronization Therapy

<table>
<thead>
<tr>
<th>Study</th>
<th>A Priori Design</th>
<th>Dupeicate Selection/Extraction</th>
<th>Comp Literature Search</th>
<th>Search for Gray Literature</th>
<th>Included/Excluded Studies Provided</th>
<th>Study Characteristics Provided</th>
<th>Study Scientific Quality Assessed and Documented</th>
<th>Scientific Quality Used in Formulated Conclusions</th>
<th>Appropriate Methods for Synthesis</th>
<th>Publication Bias Assessed</th>
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For a description of AMSTAR items, see https://amstar.ca/docs/AMSTARguideline.pdf.

AMSTAR: A MeaSurement Tool to Assess systematic Reviews; COI: conflict of interest; Comp: comprehensive.
Table 3. RCTs of Cardiac Resynchronization Therapy for the Treatment of Heart Failure

<table>
<thead>
<tr>
<th>Study</th>
<th>Dur</th>
<th>Funding Source</th>
<th>Treatment Groups</th>
<th>N</th>
<th>Percent NYHA Class</th>
<th>Mean LVEF (SD), %</th>
<th>Mean QRS (SD), ms</th>
<th>Percent ECG Pattern</th>
<th>% AF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lozano (2000)</td>
<td>3 mo</td>
<td>Unclear</td>
<td>CRT-D, ICD</td>
<td>109</td>
<td>N</td>
<td>35 57 8</td>
<td>22 (7)</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>MUSTIC-SR (2001)</td>
<td>3 mo</td>
<td>Industry</td>
<td>CRT-D, ICD</td>
<td>109</td>
<td>N</td>
<td>35 57 8</td>
<td>22 (7)</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Garrigue (2002)</td>
<td>2 mo</td>
<td>Unclear</td>
<td>CRT first, LV first</td>
<td>6 7</td>
<td>N</td>
<td>77 23</td>
<td>25 (8)</td>
<td>208 (15)</td>
<td>NR</td>
</tr>
<tr>
<td>PATH-CHF (2002)</td>
<td>1 mo</td>
<td>Industry</td>
<td>CRT first, Uni-V first</td>
<td>24 17</td>
<td>N</td>
<td>88 12</td>
<td>21 (6)</td>
<td>174 (30)</td>
<td>87</td>
</tr>
<tr>
<td>PATH-CHF II (2003)</td>
<td>3 mo</td>
<td>Industry</td>
<td>CRT first, Inactive, first</td>
<td>43 43</td>
<td>N</td>
<td>37 28</td>
<td>23 (7)</td>
<td>154 (18)</td>
<td>91</td>
</tr>
<tr>
<td>CONTAK-CD (2003)</td>
<td>3 mo</td>
<td>Industry</td>
<td>CRT-D, ICD</td>
<td>245</td>
<td>N</td>
<td>32 60 8</td>
<td>21 (7)</td>
<td>160 (27)</td>
<td>54</td>
</tr>
<tr>
<td>MIRACLE-ICD (2003)</td>
<td>6 mo</td>
<td>Industry</td>
<td>CRT-D, ICD</td>
<td>187</td>
<td>N</td>
<td>88 12</td>
<td>24 (7)</td>
<td>165 (22)</td>
<td>NR</td>
</tr>
<tr>
<td>COMPANION (2004)</td>
<td>15 mo</td>
<td>Industry</td>
<td>CRT, Usual care</td>
<td>617</td>
<td>N</td>
<td>87 13</td>
<td>20 ^a</td>
<td>160 ^a</td>
<td>69</td>
</tr>
<tr>
<td>MIRACLE-II (2004)</td>
<td>6 mo</td>
<td>Industry</td>
<td>CRT-D, ICD</td>
<td>85 101</td>
<td>NA</td>
<td>10 0</td>
<td>24 (7)</td>
<td>166 (25)</td>
<td>12</td>
</tr>
<tr>
<td>CARE-HF (2005)</td>
<td>29 mo</td>
<td>Industry</td>
<td>CRT, Usual care</td>
<td>409</td>
<td>NA</td>
<td>94 3</td>
<td>25 ^a</td>
<td>160 ^a</td>
<td>NR</td>
</tr>
<tr>
<td>RHYTHM-ICD (2004)</td>
<td>12 mo</td>
<td>Industry</td>
<td>CRT-D, ICD</td>
<td>119 59</td>
<td>NA</td>
<td>5 7</td>
<td>26 (8)</td>
<td>169 (16)</td>
<td>NR</td>
</tr>
<tr>
<td>VectOR (2005)</td>
<td>6 mo</td>
<td>Industry</td>
<td>CRT, Inactive</td>
<td>59 47 36</td>
<td>NA</td>
<td>42 58</td>
<td>26 (6)</td>
<td>176 (25)</td>
<td>NR</td>
</tr>
<tr>
<td>BELIEVE (2006)</td>
<td>12 mo</td>
<td>Unclear</td>
<td>CRT-D, LV-ICD</td>
<td>33 36</td>
<td>NA</td>
<td>42 58</td>
<td>26 (6)</td>
<td>169 (31)</td>
<td>NR</td>
</tr>
<tr>
<td>HOBIPACE (2006)</td>
<td>3 mo</td>
<td>Govt</td>
<td>CRT, RV</td>
<td>15 15</td>
<td>Mean (SD), 3.0 (0.6)</td>
<td>26 (8)</td>
<td>174 (42)</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>Piccinillo (2006)</td>
<td>1 y</td>
<td>Unclear</td>
<td>CRT-D, ICD</td>
<td>16 15</td>
<td>NA</td>
<td>33 67</td>
<td>22 (8)</td>
<td>159 (8)</td>
<td>NR</td>
</tr>
<tr>
<td>DECREASE-HF (2007)</td>
<td>6 mo</td>
<td>Industry</td>
<td>BIV-ICD, LV-ICD</td>
<td>205 101</td>
<td>NA</td>
<td>98 2</td>
<td>23 (4)</td>
<td>160 (4)</td>
<td>0</td>
</tr>
<tr>
<td>RD-CHF (2007)</td>
<td>3 mo</td>
<td>Unclear</td>
<td>CRT first, RV first</td>
<td>25 19</td>
<td>Mean (SD), 3.2 (0.4)</td>
<td>24 (10)</td>
<td>212 (28)</td>
<td>NR</td>
<td></td>
</tr>
<tr>
<td>RethinQ (2007)</td>
<td>6 mo</td>
<td>Industry</td>
<td>CRT-D, ICD</td>
<td>87 85</td>
<td>NA</td>
<td>10 99</td>
<td>25 (5)</td>
<td>107 (12)</td>
<td>Ex</td>
</tr>
<tr>
<td>Piepoli (2008)</td>
<td>12 mo</td>
<td>Unclear</td>
<td>CRT, Usual care</td>
<td>44 45</td>
<td>NA</td>
<td>90 10</td>
<td>24 (1)</td>
<td>164 (18)</td>
<td>NR</td>
</tr>
<tr>
<td>REVERSE (2008)</td>
<td>12 mo</td>
<td>Industry</td>
<td>CRT on, CRT off</td>
<td>419 191</td>
<td>18 82 NA</td>
<td>27 (7)</td>
<td>153 (21)</td>
<td>NR</td>
<td></td>
</tr>
<tr>
<td>MADIT-CRT (2009)</td>
<td>2.4 y</td>
<td>Industry</td>
<td>CRT-D, ICD</td>
<td>108 9</td>
<td>14 86 NA</td>
<td>24 (5)</td>
<td>&gt;150, 64%</td>
<td>70</td>
<td></td>
</tr>
</tbody>
</table>

Note: CRT-D = Cardiac Resynchronization Therapy, ICD = Implanted Cardioverter-Defibrillator, NYHA = New York Heart Association, LVEF = Left Ventricular Ejection Fraction, QRS = QRS Duration, ECG = Electrocardiogram, AF = Atrial Fibrillation, LBBB = Left Bundle Branch Block, RBBB = Right Bundle Branch Block, NR = Not Reported, Ex = Excluded.
Biventricular Pacemakers (Cardiac Resynchronization Therapy) for the Treatment of Heart Failure

2.02.10

and an LVEF 30% or less to an ICD alone or a CRT-D device. Randomized 1820 patients with NYHA class I (n=265) or II (n=1555) heart failure statistically significant. Interaction for class by treatment group was not given but was reported to be not however, the effect in NYHA class I patients was not statistically significant. The reduced mortality of CRT-D vs ICD for NYHA ischemic and nonischemic class II; death rate was similar between groups. Subgroup analyses found significantly accounted entirely for the difference on the primary composite outcome. The first component of the composite outcome (acute heart failure events) occurred in 22.8% of patients in the ICD alone group compared with 13.9% of patients in the CRT-D group (relative risk reduction, 39%; absolute risk reduction, 8.9%; number needed to treat, 11.2). This difference in acute heart failure events accounted entirely for the difference on the primary composite outcome. The death rate was similar between groups. Subgroup analyses found significantly reduced mortality of CRT-D vs ICD for NYHA ischemic and nonischemic class II; however, the effect in NYHA class I patients was not statistically significant. The interaction for class by treatment group was not given but was reported to be not statistically significant.

A follow-up from the MADIT-CRT trial, published by Goldenberg et al (2011), analyzed the reduction in recurrent heart failure events. This analysis supplemented the original MADIT-CRT outcome of time to first heart failure event, by comparing total heart failure events during an average follow-up of 2.6 years.

**MADIT-CRT Trial**

The largest trial published to date is the single-blind Multicenter Automatic Implantation Trial–Cardiac Resynchronization (MADIT-CRT) trial, which randomized 1820 patients with NYHA class I (n=265) or II (n=1555) heart failure and an LVEF 30% or less to an ICD alone or a CRT-D device. The MADIT-CRT trial reported a reduction for the CRT-D group on the primary outcome (ie, death or acute heart failure exacerbation). The primary end point was reached by 17.2% of patients in the CRT-D group compared with 25.3% of patients in the ICD alone group. The first component of the composite outcome (acute heart failure events) occurred in 22.8% of patients in the ICD alone group compared with 13.9% of patients in the CRT-D group (relative risk reduction, 39%; absolute risk reduction, 8.9%; number needed to treat, 11.2). This difference in acute heart failure events accounted entirely for the difference on the primary composite outcome. The death rate was similar between groups. Subgroup analyses found significantly reduced mortality of CRT-D vs ICD for NYHA ischemic and nonischemic class II; however, the effect in NYHA class I patients was not statistically significant. The interaction for class by treatment group was not given but was reported to be not statistically significant.

Adapted from Al-Majed et al (2011). AF: atrial fibrillation; Biv: biventricular; CRT: cardiac resynchronization therapy; CRT-D: cardiac resynchronization therapy with implantable cardioverter defibrillator; Dur: duration; ECG: electrocardiogram; ex: excluded; Govt: government; ICD: implantable cardioverter defibrillator; LBBB: left bundle branch block; LV: left ventricle; LVEF: left ventricular ejection fraction; NA: not applicable; NR: not reported; NYHA: New York Heart Association; RBBB: right bundle branch block; RV: right ventricle; Uni-V: univentricular.

* Median.

* Simultaneous and sequential BiV+ICD
Over this time period, there was a 38% relative reduction in heart failure events in the CRT group (hazard ratio [HR], 0.62; 95% confidence interval [CI], 0.45 to 0.85; p=0.003). On subgroup analysis, the benefit was evident in patients with left bundle branch block (LBBB; HR=0.50; 95% CI, 0.33 to 0.76; p=0.001) but not in patients without LBBB (HR=0.99; 95% CI, 0.58 to 1.69; p=0.96).

Goldenberg et al (2014) analyzed mortality in MADIT-CRT trial subjects with follow-up through 7 years, stratified by the presence or absence of LBBB. Follow-up was available for a median 5.6 years among all 1691 surviving patients enrolled in the trial, and beyond that for 854 subjects enrolled in posttrial registries. Seventy-three percent and 75% of the ICD-only and CRT-D groups, respectively, had LBBB; 69% of each group had a QRS interval of at least 150 ms. At 7-year follow-up, the cumulative rate of death from any cause among patients with LBBB was 29% in the ICD-only group compared with 18% in the CRT-D group (p=0.002; adjusted HR in the CRT-D group, 0.59; 95% CI, 0.43 to 0.80; p<0.001). The benefit associated with ICD-CRT was consistent in subgroup analysis among patients with a prolonged QRS interval (≥150 ms) and a shorter QRS interval (<150 ms). In multivariable analysis, there was no significant interaction between QRS interval and overall survival. Among patients without LBBB, there was no significant difference in the cumulative rate of death from any cause between the ICD-only and CRT-D groups.

**RAFT Trial**

A second, large RCT was the Resynchronization-Defibrillation for Ambulatory Heart Failure Trial (RAFT), which randomized 1798 patients with class II or III heart failure and an LVEF of 30% or less to CRT-D or ICD alone, with a mean follow-up 40 months. Unlike most previous trials, this trial did not confine enrollment to patients with sinus rhythm but also allowed patients with atrial arrhythmias to participate. However, the number of patients who were not in sinus rhythm was only 12.8% (229/1798). On formal quality assessment, this trial met all quality indicators and was given a “good” quality rating.

The primary outcome (death from any cause or hospitalization for heart failure) was reduced in the CRT-D group (33.2%) compared with the ICD alone group (40.3%; p<0.001). There were significant reductions in both individual components of the primary outcome, overall mortality (20.8% vs 26.1%; p=0.003) and hospitalizations (19.5% vs 26.1%; p<0.001), all respectively. When restricted to patients with NYHA class II heart failure, improvements in the outcomes of mortality and hospitalizations remained significant. The mortality rate for class II patients in the CRT-D group was 15.5% vs 21.1% in the ICD alone group (HR=0.71; 95% CI, 0.56 to 0.91; p<0.006). Hospitalizations for class II patients occurred in 16.2% of patients in the CRT-D group and 21.1% in the ICD alone group (HR=0.70; 95% CI, 0.55 to 0.89; p<0.003).

In a preplanned subgroup analysis of RAFT data focusing on hospitalization rates over the 18-month follow-up period, Gillis et al (2014) reported that the fewer patients in the CRT-D group (11.3%) were hospitalized for heart failure than those in the ICD alone group (15.6%; p=0.003). Although the total number of
hospitalizations for any cause was lower in the CRT-D group (1448 vs 1553; p=0.042), patients randomized to CRT-D had more hospitalizations for device-related indications (246 vs 159; p<0.001).

Subgroup analyses from RAFT reported that female sex, a QRS interval of 150 ms or more, an LVEF less than 20%, and QRS morphologic features were predictive of benefit. Of these factors, the QRS interval was the strongest. Patients with a QRS interval of 150 ms or more had an RR for the primary outcome of approximately 0.50, compared with an RR of approximately 1.0 for patients with a QRS interval less than 150 ms (p=0.003 for the difference between the RRs). There was a trend for greater improvement in patients with sinus rhythm compared with patients with atrial arrhythmias, but this difference was not statistically significant.

**Safety of CRT Placement**

Several systematic reviews have reported on complication rates. Three reviews published after 2010 are shown in Table 4. Van Rees et al (2011) focused on complications from CRT treatment. This analysis included 7 trials of CRT that reported on in-hospital mortality and complications related to device placement. In all 7 CRT trials, the device was placed percutaneously without a thoracotomy. In-hospital mortality occurred at a rate of 0.3%, and 30-day mortality was 0.7%. The most common complications related to placement of the left ventricular (LV) lead. Lead dislodgement occurred in 5.9% of patients. Other LV lead placement complications included coronary vein dissection (1.3%) and coronary vein perforation (1.3%). Pneumothorax occurred in 0.9% of patients, and hematoma at the insertion site occurred in 2.4% of patients. Other systematic reviews have reported similar implant success rates, 30-day mortality, and lead problems.

### Table 4. Systematic Reviews Assessing the Safety of CRT for Treatment of Heart Failure

<table>
<thead>
<tr>
<th>Study</th>
<th>Dates</th>
<th>Population</th>
<th>Studies (N)</th>
<th>Designs</th>
<th>Outcome Measures</th>
<th>Results (95% CI), %</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRT</td>
<td>Through 2010</td>
<td>Undergoing elective CRT</td>
<td>7 RCTs (N=4512)</td>
<td>RCTs</td>
<td>Implant success rate</td>
<td>92.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>In-hospital mortality</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mortality within 30 days</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pneumothorax</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Coronary dissection</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Coronary perforation</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pocket hematoma</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lead dislodgement</td>
<td>5.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Implant success rate</td>
<td>94.4 (93.8 to 94.8)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mechanical complications</td>
<td>3.2 (2.8 to 3.6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Device malfunction</td>
<td>1.9 (1.5 to 2.4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lead problems</td>
<td>6.2 (5.6 to 6.8)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Infections</td>
<td>1.4 (1.1 to 1.7)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Peri-implantation death</td>
<td>0.3 (0.2 to 0.5)</td>
</tr>
<tr>
<td><strong>CRT vs ICD</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adabag et al (2011)</td>
<td>1960-2010</td>
<td>NYHA class I/II, EF ≤40%, QRS interval ≥120 ms</td>
<td>4 studies (N=4414)</td>
<td>RCTs</td>
<td>In-hospital death</td>
<td>0.05 vs 0.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pneumothorax</td>
<td>1.5 vs 0.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lead dislodgment</td>
<td>5.1 vs 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Coronary sinus dissection</td>
<td>0.8 vs 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Implant failure</td>
<td>6.6 vs &lt;0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Any adverse event</td>
<td>18 vs 4</td>
</tr>
</tbody>
</table>

CI: confidence interval; CRT: cardiac resynchronization therapy; EF: ejection fraction; NYHA: New York Heart Association; RCT: randomized controlled trial.
Hosseini et al (2017) reported on in-hospital complication rates of CRT from 2003 to 2013 using data from the National Inpatient Sample and the Nationwide Inpatient Sample (NIS), the largest all-payer inpatient database of hospital discharge records in the United States. The NIS includes approximately 20% of discharges from U.S. hospitals and sampling weights provided by the NIS can be used to produce national estimates from NIS data. A total of 92,480 unweighted records (corresponding to 376,045 weighted records) were analyzed. In patients receiving CRT-D and CRT with a pacemaker (CRT-P), 6.04% and 6.54% had at least 1 complication, respectively. The overall rate of at least 1 complication increased from 5.86% in 2003 to 6.95% in 2013 (p=0.01) for CRT-D and from 5.46% to 7.11% (p=0.01) in CRT-P. In the CRT-D group, the overall increase in complications was driven by increases in pericardial complications, vascular complications, and postoperative infections. In the CRT-P group, the overall increase in complications was driven by an increase in vascular complications. The most common adverse outcomes were pulmonary complications (1.48%), hemorrhage/hematoma (1.41%), and infection (1.17%). The in-hospital mortality rate was 0.70% for CRT-D and 1.08% for CRT-P.

**Predictors of Response to CRT**

For patients who meet indications for CRT treatment, there is a large variability in the magnitude of response. Some patients do not respond at all, while others have very substantial benefit. As a result, there is interest in defining the clinical features that predict response to better target therapy to those who will benefit most. There is a large body of literature examining predictors of outcomes after CRT placement, and numerous clinical and demographic factors have been identified that predict response. A smaller number of predictors have been proposed as potential selection criteria for CRT placement.

An example of a study examining general predictors of outcome is The Predictors of Response to Cardiac Resynchronization Therapy (PROSPECT) trial. This prospective, multicenter trial evaluated the utility of echocardiographic parameters to predict response to CRT. Trial results indicated that the 12 individual echocardiographic parameters varied widely in ability to predict response. The sensitivity of these individual measures ranged from 6% to 74%, and the specificity ranged from 35% to 91%. The authors concluded it was unlikely that these measures could improve patient selection for CRT. Three additional selection factors are reviewed here: QRS interval/morphology, prolonged PR interval, and ventricular dyssynchrony on echocardiography.

**QRS Interval/Morphology**

It is well accepted that patients with a QRS complex of less than 120 ms who are not selected for dyssynchrony do not benefit from CRT. LESSER-EARTH was an RCT designed to compare CRT with no CRT in patients with a QRS complex of less than 120 ms, whether or not ventricular dyssynchrony was present. This trial was terminated early after 85 patients had been enrolled. Interim analysis revealed futility in achieving benefit on the primary outcomes and a trend toward greater adverse events.
A more controversial issue is whether patients with a moderately prolonged QRS interval (120-150 ms) benefit from CRT, or whether the benefit is confined to subsets of patients such as those with a markedly prolonged QRS interval (>150-160 ms) or LBBB. Several meta-analyses of the association between QRS interval and outcomes have been published. Two patient-level meta-analyses have evaluated QRS duration. In a patient-level meta-analysis of data from 3 RCTs (total N=4076 patients), Zusterzeel et al (2014) evaluated whether women with LBBB benefit from combined CRT-D implantation at a shorter QRS interval than men with LBBB. For patients with LBBB and a QRS interval from 130 to 149 ms, women experienced a significant reduction in risk of heart failure or death (absolute risk difference between CRT-D and ICD alone, 23%; HR=0.24; 95% CI, 0.11 to 0.53; p<0.001), while men had no significant reduction in risk of heart failure or death (absolute risk difference, 4%; HR=0.85; 95% CI, 0.60 to 1.21; p=0.38). Men and women with LBBB and QRS durations longer than 150 ms benefited from CRT-D therapy, while neither men nor women with LBBB and QRS intervals shorter than 130 ms benefited. This trial’s conclusion is strengthened because of the patient-level data examined, but somewhat limited because not all RCTs had patient-level data available.

In a second review including individual patient data, Woods et al (2015) performed a network meta-analysis of ICDs to inform a National Institute for Health and Care Excellence guidance. Thirteen RCTs with 12,638 patients were included. Estimates of CRT effect on mortality were given for 16 subgroups (men vs women; <60 years vs ≥60 years; QRT interval ≥120 ms to <150 ms vs ≥ 150 ms; LBBB vs no LBBB; see Table 5). In women in both age groups, CRT-D statistically significantly reduced mortality compared with medical therapy alone for both QRS intervals (≥120 ms to <150 ms and ≥150 ms) with and without LBBB. Also, in women of both age groups, CRT-P significantly reduced mortality compared with medical therapy alone with QRS intervals of 150 ms or more and LBBB. CRT-D significantly reduced mortality compared with ICD alone for women younger than 60 with a QRS of 150 ms or more and LBBB, women older than 60 with QRS intervals ranging from 120 ms to 150 ms and LBBB, and women older than 60 with QRS intervals of 150 ms or more with or without LBBB. For men in both age groups, CRT-D reduced mortality compared with medical therapy alone in both QRS groups with and without LBBB. However, CRT-P significantly improved survival compared with medical therapy alone only in men older than 60 years with QRS intervals of 150 ms or more and LBBB. Likewise, CRT-D improved survival compared with ICD alone in men older than 60 years with QRS intervals of 150 ms or more and LBBB.

**Table 5. Subgroup-Specific Treatment Effects in a Network Meta-Analysis**

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age</th>
<th>QRS</th>
<th>LBBB</th>
<th>CRT-D vs MT</th>
<th>CRT-P vs MT</th>
<th>CRT-D vs ICD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>HR</td>
<td>95% CI</td>
<td>HR</td>
</tr>
<tr>
<td>Women</td>
<td>&lt;60</td>
<td>≥120 to</td>
<td>N</td>
<td>0.62</td>
<td>0.40 to 0.96</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt;150</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td>&lt;60</td>
<td>≥120 to</td>
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<th>HR</th>
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**Men \≥60**

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Adapted from Woods et al (2015).14

CI: confidence interval; CRT-D: cardiac resynchronization therapy with implantable cardioverter defibrillator; CRT-P: cardiac resynchronization therapy with pacemaker; HR: hazard ratio; ICD: implantable cardioverter defibrillator; LBBB: left bundle branch block; MT: medical therapy; N: no; Y: yes

Other meta-analyses have come to similar conclusions, reporting benefits for patients with a QRS interval of more than 150 ms, and little to no benefit for patients with shorter QRS intervals.57-62 In one of these studies, the benefit of CRT was confined to patients with LBBB.60 There was no benefit demonstrated for patients with right bundle branch block or intraventricular conduction delay. These reviewers suggested that QRS morphology may be as important, or more important, than QRS duration in predicting response to CRT.

Peterson et al (2013) published results of a retrospective cohort study of Medicare beneficiaries who underwent combined CRT-D placement to assess associations between QRS interval and morphology and outcomes.63 Among 24,169 patients admitted for CRT-D placement and followed for up to 3 years, rates of 3-year mortality and 1-year all-cause rehospitalization were lowest in patients with LBBB and QRS intervals of 150 ms or more. Patients with no LBBB and QRS intervals from 120 to 149 ms had an adjusted HR of 1.52 (95% CI, 1.38 to 1.67) after controlling for a number of clinical and demographic confounders (vs those with LBBB and markedly prolonged QRS interval).

**Prolonged PR Interval**

The data are inconsistent on the association between PR interval and outcomes in CRT.

Kutyifa et al (2014) evaluated whether prolonged PR predicts heart failure or death among 537 (30%) of MADIT-CRT trial subjects who did not have an LBBB.64 Among the 96 patients with a prolonged PR interval, compared with ICD alone, CRT-D treatment was associated with reduced risk of heart failure or death (HR=0.27; 95% CI, 0.13 to 0.57; p<0.001). In contrast, among the 438 subjects...
with a normal PR interval, CRT-D treatment was associated with a nonsignificant trend toward increased risk of heart failure or death (HR=1.45; 95% CI, 0.96 to 2.19; p=0.078). In long-term follow-up of MADIT-CRT, the reduction in mortality for CRT-D vs ICD in those with prolonged PR was similar to the short-term results (HR=0.24; 95% CI, 0.07 to 0.80), but the increase in mortality for CRT-D vs ICD in normal PR was larger than in the short-term results (HR=2.27; 95% CI, 1.16 to 4.44).65

In an analysis of 26,451 CRT-eligible (ejection fraction ≤35, QRS interval ≥120 ms) patients from the National Cardiovascular Data Registry, Friedman et al (2016) examined the association between prolonged PR interval (≥230 ms), receipt of CRT-D vs ICD-only, and outcomes.66 All Medicare beneficiaries who receive a primary prevention ICD are enrolled in this ICD registry. Patients with a prolonged PR interval were more often male, older, with comorbid ischemic heart disease, atrial arrhythmias, cerebrovascular disease, diabetes, and chronic kidney disease. After adjusting for other risk factors, a prolonged PR was associated with increased risk of heart failure hospitalization or death among CRT-D (HR=1.2; 95% CI, 1.1 to 1.3; p<0.001) compared with normal PR interval. There was no association between PR interval and hospitalization or death among ICD-only recipients (HR=1.1; 95% CI, 1.0 to 1.2; p=0.17). CRT-D was associated with lower rates of heart failure hospitalization or death compared with ICD-only among patients who had a PR interval less than 230 (HR=0.79; 95% CI, 0.73 to 0.85; p<0.001) but not with PR interval of 230 or more (HR=1.01; 95% CI, 0.87 to 1.17; p=0.90). Limitations of this analysis included lack of randomization (ie, residual confounding) and potential inaccuracies in registry data.

Lin et al (2017) reported on a secondary analysis of mortality and hospitalization including 903 patients stratified by normal (255 patients ≤230 ms) or prolonged PR interval (53 patients >230 ms) from the medical therapy and CRT-D arms of the COMPANION trial.67 Mortality was significantly reduced in patients with a prolonged PR interval who received CRT-D vs medical therapy (HR=0.37; 95% CI, 0.21 to 0.67). However, the association was smaller and not significantly significant in those with a normal PR interval (HR=0.73; 95% CI, 0.52 to 1.03).

**Ventricular Dyssynchrony**

Observational studies of patients who meet criteria for CRT have shown that measures of dyssynchrony on echocardiography correlate with treatment response, as defined by improvements in LV end-systolic volume (LVESV), ejection fraction, or clinical criteria.68 This finding prompted investigation of whether ventricular dyssynchrony could discriminate between responders and nonresponders to CRT, for patients who would otherwise qualify for CRT and for those who would not (ie, those with a narrow QRS interval).

A small RCT that compared CRT outcomes in patients who had ventricular dyssynchrony with those without was published by Diab et al (2011).69 A total of 73 patients with NYHA class II, III, IV heart failure were evaluated, 44 of whom had dyssynchrony on echocardiography. These 44 patients were randomized to CRT-D or ICD alone. Outcomes measures were maximal oxygen consumption
(Vo$_2$max), NYHA class, and echocardiographic parameters. At 6-month follow-up, more patients in the CRT group had an increase of at least 1 mL/kg/min in Vo$_2$max (62% vs 50% p=0.04). There were significant within-group improvements in NYHA class and echocardiographic measures, but between-group comparisons with the no CRT group were not statistically significant.

The NARROW-CRT RCT compared CRT using dual-chamber ICD among patients who had heart failure (NYHA class II-III) of ischemic origin, ejection fraction of 35% or less, QRS interval less than 120 ms, and marked mechanical dyssynchrony on echocardiogram.70 One hundred twenty patients were randomized to CRT (n=60) or ICD (n=60). For the trial’s primary outcome (heart failure clinical composite score), compared with those in the ICD group, patients in the CRT were more likely to have improved clinical composite scores at 1 year postimplantation (41% vs 16%, p=0.004). Patients in the CRT group had higher rates of avoiding the combined end point of heart failure hospitalization, heart failure death, and spontaneous ventricular fibrillation (p=0.028).

The EchoCRT study was intended to evaluate the role of CRT for subjects with heart failure (NYHA class III or IV) with narrow QRS interval (<130 ms) and echocardiographic evidence of ventricular dyssynchrony. All enrolled patients were implanted with a CRT-D, and then randomized to CRT with the device on or off. The study was stopped for futility after enrollment of 809 patients; results from the enrolled patients who had been followed for a mean of 19.4 months were reported by Ruschitzka et al (2013).71 Four hundred four patients were randomized to the CRT group and 405 to the control group. The primary efficacy outcome (death from any cause or hospitalization for worsening heart failure) occurred in 116 (28.7%) of 404 patients in the CRT group and 102 (25.2%) of 405 in the control group (HR with CRT, 1.20; 95% CI, 0.92 to 1.57; p=0.15). There was a significantly higher death rate in the CRT group: 45 (11.1%) of 404 patients died in the CRT group while 26 (6.4%) of 50 died in the control group (HR=1.81; 95% CI, 1.11 to 2.93; p=0.02).

The Resynchronization Therapy in Normal QRS Trial (RethinQ study) randomized 172 patients with a narrow QRS interval and evidence of dyssynchrony to a CRT device, turned on or not, who were followed for 6 months.36 CRT-treated patients (46%) were no more likely than non-CRT patients (41%) to show improvement (meet the end point of improvement in exercise capacity [Vo$_2$peak]). A subset of patients with QRS intervals of 120 to 130 ms or more showed improvement (p=0.02), whereas those with a QRS interval less than 120 ms did not (p=0.45).

Section Summary: Cardiac Resynchronization Therapy for Heart Failure

**NYHA Class III or IV Heart Failure**

There is a large body of clinical trial evidence that supports the use of CRT in patients with NYHA class III or IV heart failure. Results of RCTs have consistently reported that CRT treatment leads to reduced mortality, improved functional status, and improved quality of life (QOL) for patients with NYHA class III or IV heart failure.
**NYHA Class I or II Heart Failure**

For patients with mild heart failure (NYHA class I or II), at least 4 RCTs of CRT have been published. A mortality benefit was reported in 1 trial (RAFT). This trial was free of major bias and reported a fairly large absolute difference in overall mortality (5.3%). None of the other 3 RCTs reported a mortality difference. While 2 of the other 3 trials were underpowered to detect differences in mortality, MADIT-CRT was approximately the same size as RAFT and did not show any improvement in mortality. In a subgroup analysis of the MADIT-CRT trial, a mortality benefit was shown in patients with LBBB. It is possible that the sicker patient population and longer follow-up in RAFT accounted for the mortality difference. Among other outcome measures, hospitalizations for heart failure showed consistent improvements, but QOL and functional status did not. Most patients in these trials had class II congestive heart failure. Hence it is not possible to determine separately whether patients with class I heart failure achieved benefit. However, when mild heart failure is considered as a group (class I or II), these data are sufficient to determine that outcomes are improved for patients with mild heart failure.

**Predictors of Response**

The presence of dyssynchrony on echocardiography may risk-stratify patients, but it is not a good discriminator of responders from nonresponders. A QRS interval of more than 150 ms or the presence of LBBB appears to discriminate well between responders and nonresponders and represents a potential factor in selecting patients for CRT treatment. Subgroup analyses across multiple RCTs, corroborated by pooling of these subgroups in meta-analyses, have reported that QRS intervals of 150 to 160 ms or more or the presence of LBBB are accurate in discriminating responders from nonresponders. Subgroup analyses of 2 RCTs and 1 registry study have provided inconsistent results on the role of prolonged PR interval. Two patient-level meta-analyses reported that women might benefit at a shorter QRS interval than men.

**CRT for Heart Failure and Atrial Fibrillation**

There is controversy whether CRT leads to health outcome benefits for patients with atrial fibrillation (AF). Many experts believe that, if CRT is used, it should be combined with ablation of the atroventricular (AV) node to avoid transmission of atrial impulses through the node that might result in rapid ventricular rates, thus undermining the efficacy of CRT. Most trials of CRT have excluded patients with permanent AF; however, 2 trials (APAF, MUSTIC-AF) have examined CRT specifically in this population, and other RCTs have reported subgroup analyses in patients with permanent or intermittent AF. Systematic reviews of observational studies have also been performed, and analysis from the National Cardiovascular Data Registry is available.

**Randomized Controlled Trials**

Kalscheur et al (2017) reported on a comparison of outcomes between CRT-P and medical therapy in patients with intermittent AF or atrial flutter (n=293) and those without (n=887) in COMPANION. Intermittent AF and atrial flutter were
determined from medical history and chart review at enrollment. Cox proportional hazard models were used to estimate effects. The interaction between history of intermittent AF and atrial flutter and CRT treatment group was statistically significant for both death and hospitalization outcomes (p<0.05). In CRT-P group, there was a significant reduction in the composite outcome of death or any hospitalization (HR=0.73; 95% CI, 0.60 to 0.89; p=0.002) and in the composite of death or heart failure hospitalization (HR=0.53; 95% CI, 0.41 to 0.68; p<0.001). In contrast, in the intermittent AF and atrial flutter group (n=293), CRT-P did not result in improved outcomes vs medical therapy (death or any hospitalization HR=1.16; 95% CI, 0.83 to 1.63; p=0.38; death or heart failure hospitalization HR=0.97; 95% CI, 0.64 to 1.46; p=0.88).

The 2011 Ablate And Pace Therapy for Permanent Atrial Fibrillation (APAF) RCT compared CRT with right ventricular (RV) pacing alone in patients with AF. A total of 186 patients had AV nodal ablation, implantation of a CRT device, and were then randomized to echo-optimized CRT or RV pacing alone and followed for a median of 20 months. The primary outcome measure was a composite of death from heart failure, hospitalization for heart failure, or worsening heart failure. This combined end point occurred in 11% of the CRT group and 26% of the RV pacing group (HR=0.37; 95% CI, 0.18 to 0.73; p=0.005). For the individual outcome measures, there was no significant reduction in mortality (HR=1.57; 95% CI, 0.58 to 4.27; p=0.37), but there were significant reductions in hospitalizations (HR=0.20; 95% CI, 0.06 to 0.72; p=0.013) and worsening heart failure (HR=0.27; 95% CI, 0.12 to 0.58; p=0.37). There were no differences in outcomes on subgroup analysis, including analysis by ejection fraction, NYHA class, and/or QRS interval.

In the MUltisite STimulation In Cardiomyopathies and Atrial Fibrillation (MUSTIC-AF) trial, 59 NYHA class III patients with LV systolic dysfunction, slow and permanent AF of greater than 3 months duration, and a paced QRS interval greater than 200 ms were randomized in a single-blinded, crossover design to RV vs biventricular pacing with 3 months for each period. The primary outcome was the 6-minute walk distance; secondary outcomes were Vo2max, QOL, hospitalizations, patients' preferred study period and mortality. Only 37 patients completed both crossover periods. In intention-to-treat analyses, no significant differences were observed between assigned groups.

A post hoc analysis of patients with AF enrolled in RAFT was published by Healey et al (2012). Randomization in this trial was stratified for the presence of AF, allocating 114 patients with AF to the CRT plus defibrillator group and 115 patients with AF to the defibrillator group alone. There was no difference between groups in the primary outcome of death or hospitalization due to heart failure (HR=0.96; 95% CI, 0.65 to 1.41; p=0.82). There were also no differences in cardiovascular death or functional status. There was a trend for patients in the CRT group to have fewer hospitalizations for heart failure than those in the defibrillator-alone group, but the difference was not statistically significant.
Systematic Reviews

A systematic review by Wilton et al (2011) compared outcomes of CRT in patients with and without AF.\(^7\) This analysis included 23 observational studies enrolling 7495 patients, 1912 of whom had AF. Outcomes in patients with AF were less favorable on all measures. They included overall mortality (RR=1.5; 95% CI, 1.08 to 2.09; \(p=0.015\)), nonresponse to CRT (RR=1.32; 95% CI, 1.12 to 1.55; \(p=0.001\)), change in Minnesota Living with Heart Failure Questionnaire QOL score (mean difference, -4.1; 95% CI, -1.7 to -6.6; \(p=0.001\)), and change in 6-minute walk distance (mean difference, -14.1 meters; 95% CI, -28.2 to 0.0 meters; \(p=0.05\)). Five studies compared outcomes of patients with AF who had or did not have AV nodal ablation. A pooled analysis from these studies indicated that AV nodal ablation was associated with a lower rate of nonresponse (RR=0.40; 95% CI, 0.28 to 0.58; \(p<0.001\)).

A systematic review by Ganesan et al (2012) evaluated the role of AV node ablation in patients with AF treated with CRT.\(^7\) Reviewers included nonrandomized studies that reported on outcomes for CRT and medical therapy. Six studies were included, enrolling 768 patients, 339 of whom underwent AV node ablation and 429 of whom did not. AV nodal ablation was associated with improvements in the outcomes of all-cause mortality (RR=0.42; 95% CI, 0.26 to 0.68), cardiovascular mortality (RR=0.44; 95% CI, 0.24 to 0.81), and change in NYHA class (mean difference, -0.34; 95% CI, -0.56 to -0.13; \(p=0.002\)).

Yin et al (2014), in another systematic review and meta-analysis, evaluated the effects of AV nodal ablation; it included 13 observational studies (total N=1256 patients) of CRT patients with AF who received AV nodal ablation or medical therapy.\(^7\) In pooled analysis of patients with inadequate biventricular pacing (<90% biventricular pacing), AV nodal ablation was associated with lower risk of all-cause mortality than no ablation (RR=0.63; 95% CI, 0.42 to 0.96), along with a reduced risk of CRT nonresponse (RR=0.41; 95% CI, 0.31 to 0.54). In contrast, among patients with adequate biventricular pacing (>90% biventricular pacing), AV nodal ablation was not significantly associated with risk of CRT nonresponse (RR=0.97; 95% CI, 0.72 to 1.32).

Registry Data

Khazanie et al (2016) analyzed data from the National Cardiovascular Data Registry, which linked with Medicare claims and compared beneficiaries who receive CRT-D with those who received ICD alone.\(^7\) The dataset included 8951 patients with heart failure and AF with a QRS interval of 120 ms or more and a LEVF of 35% or less who had a registry record for CRT-D or ICD placement between 2006 and 2009 who were discharged alive to home. The authors used Cox proportional hazard models and inverse probability-weighted estimates to compare outcomes. CRT-D was associated with lower mortality (HR=0.83; 95% CI, 0.75 to 0.92), all-cause readmission (HR=0.86; 95% CI, 0.80 to 0.92), and heart failure readmission (HR=0.68; 95% CI, 0.62 to 0.76) compared with ICD alone.
Section Summary: CRT for Heart Failure and Atrial Fibrillation
There is insufficient evidence to determine whether CRT improves outcomes for patients with AF and heart failure. Data from 2 RCTs enrolling only patients with AF showed different results, with one reporting improvements for patients with AF and another reporting no significant improvements. Subgroup analyses of the RAFT and COMPANION trials did not show the benefit of CRT in patients with permanent or intermittent AF. Similarly, systematic reviews of observational studies have reported conflicting results. A registry study including almost 9000 Medicare beneficiaries reported significant improvements in mortality and hospitalizations for patients with heart failure and AF treated with CRT-D compared with ICD alone.

CRT for Heart Failure and AV Nodal Block
Patients with heart failure may require pacemakers for symptomatic bradycardia; those patients have a high risk of mortality or require heart transplant due to progressive heart failure, which is thought to be due, in part, to dyssynchronous contraction caused by RV pacing.

In 2014, the U.S. Food and Drug Administration expanded the indications for several CRT devices to include patients with NYHA functional class I, II, or III heart failure and an LVEF of 50% or less, and AV block. A high percentage of these patients are expected to require ventricular pacing that cannot be managed with algorithms to minimize RV pacing. The Food and Drug Administration approval was based on results of the BLOCK HF trial, in which patients with an indication for a pacemaker and NYHA class I, II, or III heart failure were implanted with a combined CRT-P or CRT-D (if indicated) and randomized to standard RV pacing or biventricular pacing. Patients with permanent atrial arrhythmias and intrinsic AV block or AV block due to AV node ablation could be enrolled if they met other enrollment criteria. At baseline, patients met the requirement for ventricular pacing, either because of documented third-degree AV block or a second-degree AV block or a PR interval of 300 ms or more when paced at 100 beats per minute.

Nine-hundred eighteen patients were enrolled, 691 of whom underwent randomization after 30 to 60 days of RV pacing, during which time appropriate pharmacologic therapy was established. Approximately half of all enrolled patients (51.6% of the CRT group, 54.1% of the RV pacing group) had AF. After accounting for censored data due to missing measures of LVESV index, the primary outcome (first event of death from any cause, an urgent care visit for heart failure requiring intravenous therapy, or an increase in the LVESV index of ≥15%) occurred in 160 (45.8%) of 349 patients in the biventricular pacing group and in 190 (55.6%) of 342 in the RV pacing group. In a hierarchical Bayesian proportional hazards model, the hazard ratio for the primary outcome was 0.74 for the comparison between biventricular pacing and RV pacing (95% CI, 0.60 to 0.90; posterior probability of HR being ≤1, 0.9978, which is greater than the prespecified threshold for superiority of biventricular to RV pacing of 0.9775). The prespecified secondary outcomes of an urgent care visit for heart failure, death or hospitalization for heart failure, and hospitalization for heart failure were less likely in the biventricular pacing group; however, the secondary outcome of death alone did not differ
significantly between groups. LV lead-related complications occurred in 6.4% of patients. In another publication from the BLOCK HF study, reported by Curtis et al (2016), patients in the CRT group showed greater improvements in NYHA class at 12 months (19% improved, 61% unchanged, 17% worsened) compared with the RV group (12% improved, 61% unchanged, 23% worsened; posterior probability, 0.99). At 6 months, Packer clinical composite score was improved, unchanged, or worsened in 53%, 24%, and 24% in the CRT group compared with 39%, 33%, and 28% in the RV arm (posterior probability, ≥0.99), respectively. The Packer clinical composite score classifies patients into 3 categories (improved, worsened, unchanged) using clinical outcomes, heart failure status, and patient symptoms.

Results of the BLOCK HF RCT were compared with results from the an earlier trial (PACE), in which 177 patients with bradycardia and a normal ejection fraction in whom a biventricular pacemaker had been implanted were randomized to biventricular pacing (n=89) or RV apical pacing (n=88). In the trial’s main results, at 12 months postenrollment, subjects who underwent standard pacing had lower mean LVEF than those randomized to biventricular pacing (54.8% vs 62.2%; p<0.001) and higher mean LVESV (35.7 mL vs 27.6 mL; p<0.001). No significant differences were reported for QOL or functional measures or rates of heart failure hospitalization. In long-term follow-up over a mean duration of 4.8 years among 149 subjects, biventricular pacing continued to be associated with improved LV functioning and less LV remodeling. Also, during long-term follow-up, heart failure hospitalization occurred more frequently in the RV pacing group (23.9% vs 14.6%; p<0.001).

Several other RCTs have also corroborated the results of the BLOCK and PACE trials. These trials reported improvements in physiologic parameters of LV function and improvements in functional status measured by the 6-minute walk test. Some, but not all, of these trials also reported improvements in QOL for patients treated with CRT.

Section Summary: CRT for Heart Failure and AV Nodal Block
For patients who have AV nodal block, some degree of LV dysfunction, and who would not necessarily meet conventional criteria for CRT but would require ventricular pacing, a large RCT has demonstrated improvements in heart failure–related hospitalizations and urgent care visits among patients treated with CRT instead of RV pacing alone. For patients who require ventricular pacing but have no LV dysfunction, results of a small RCT have suggested that biventricular pacing is associated with improved measures of cardiac function, but the trial was small and underpowered to detect differences in clinical outcomes.

Triple-Site CRT
Triple-site CRT, or triventricular pacing, is a variation of conventional CRT that uses an additional pacing lead. The rationale behind triventricular pacing is that a third pacing lead may improve electromechanical synchrony, and thereby lead to better outcomes. To demonstrate improved outcomes, RCTs are needed that compare outcomes of triple-site CRT with conventional CRT.
Five RCTs were identified for this review\textsuperscript{85-89} and are summarized in Table 6. The largest published trial, by 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).\textsuperscript{87} After a follow-up of 1 year, more patients in the conventional arm (30%) were in NYHA class III or IV heart failure than those in the triple-site CRT group (12.5%; \( p < 0.05 \)). Implantation success was similar in the triple-site (94%) and conventional groups (98%; \( p = \text{NS} \)), but triple-site implantation was associated with longer surgical time and a higher fluoroscopic exposure. Also, more patients in the triple-site group required additional procedures (33% vs 16%, \( p < 0.05 \)).

The other 4 trials were smaller, enrolling between 43 and 76 patients. Follow-up in these studies was generally short, with the longest being 1 year. Outcomes reported varied across studies and were a mix of physiologic measures, functional status, and QOL. No outcome measures reported were common across all studies. Three of the 4 studies reported significant improvements on at least 1 outcome measure, and the fourth study reported no significant differences for the 3 outcomes measured. Adverse events were not well-reported.

### Table 6. Randomized Controlled Trials Comparing Triple-Site CRT With Standard CRT

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<td></td>
<td></td>
<td>&lt;0.05</td>
<td>&lt;0.001</td>
<td>&lt;0.05</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Anselme et al (2016)\textsuperscript{88}</td>
<td>76</td>
<td>Triple-site CRT</td>
<td>+50</td>
<td>NR</td>
<td>78.8%</td>
<td>NR</td>
<td>-8.4</td>
<td>-15.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Standard CRT</td>
<td>+73</td>
<td>NR</td>
<td>81.6%</td>
<td>NR</td>
<td>-8.4</td>
<td>-15.0</td>
</tr>
<tr>
<td>( p )</td>
<td></td>
<td></td>
<td>0.40</td>
<td>0.90</td>
<td>0.20</td>
<td>0.33</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Pappone et al (2015)\textsuperscript{88}</td>
<td>44</td>
<td>Triple-site CRT</td>
<td>NR</td>
<td>NR</td>
<td>76%</td>
<td>+15%</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Standard CRT</td>
<td>NR</td>
<td>NR</td>
<td>57%</td>
<td>+5%</td>
<td>NR</td>
<td>NR</td>
</tr>
</tbody>
</table>

CRT: cardiac resynchronization therapy; MLHFQ: Minnesota Living with Heart Failure Questionnaire; NR; not reported; NYHA: New York Heart Association; QOL: quality of life; 6MWT: 6-minute walk test.

\textsuperscript{a} All patients had triple-site device implanted. Device programmed to triple-site or standard CRT randomly.

\textsuperscript{b} Percentage of patients in NYHA class III/IV heart failure.

\textsuperscript{c} Percentage of patients who improved at least 1 NYHA class.

Zhang et al (2018) conducted a meta-analysis of RCTs and comparative observational studies (total \( N = 251 \) patients) that evaluated similar outcomes.\textsuperscript{90} The meta-analysis included 1 RCT (Anselme et al [2016]\textsuperscript{85}, described above), 2 randomized crossover studies, and 2 nonrandomized comparative studies. Two different pacing modalities were used. One type used 1 lead in the right ventricle...
and leads in 2 different tributaries in the left ventricle. The other used 2 leads in the right ventricle. Patients in the triple-site pacing group had greater improvement in LVEF (weighted mean difference, 4.04; 95% CI, 2.15 to 5.92; p<0.001) and NYHA classes (weighted mean difference, -0.27; 95% CI, -0.42 to -0.11; p=0.001). However, there were no significant differences in LV end-diastolic volume or LVESV, 6-minute walk distance, or Minnesota Living with Heart Failure Questionnaire.

**Section Summary: Triple-Site CRT**
For the use of CRT with triple-site pacing requiring implantation of an additional lead, 5 small RCTs with limited follow-up and a meta-analysis that included nonrandomized studies were identified. All trials except one reported improved outcomes on at least 1 measure of functional status and QOL with triple-site CRT compared with conventional CRT. However, the outcomes reported differed across studies, with no common outcomes reported by all studies. Triple-site CRT was also associated with higher radiation exposure and a greater number of additional procedures postimplantation. Modest improvements in some outcome measures were found in the meta-analysis. Larger, high-quality RCTs are needed to better define the benefit-risk ratio for triple-site CRT compared with conventional CRT.

**CRT Combined With Remote Fluid Monitoring**
Intrathoracic fluid status monitoring has been proposed as a more sensitive way to monitor fluid status leading to prompt identification of impending heart failure, permitting early intervention, and potentially decreased rates of hospitalization.

**Randomized Controlled Trials**
Three RCTs were identified that compared management of patients with heart failure using remote fluid monitoring to usual monitoring; these trials are summarized in Table 7.91-93 Luthje et al (2015) was an unblinded, single-site RCT sponsored by the manufacturer of the OptiVol device.92 Patients in the remote monitoring group had alarms set for a rising fluid index, with most patients having their diuretic increased by 50% in response to an alert. Median follow-up was not reported. Outcomes were reported as 1-year estimates using Cox proportional hazards. Four patients were lost to follow-up. Domenichini et al (2016) was an unblinded, single-site RCT sponsored by the U.K. National Health Service.91 Patients in the remote monitoring group had alarms set for a rising fluid index, with most patients having their diuretic increased by 50% in response to an alert. Median follow-up was 375 days (range, 350-430 days). One patient was lost to follow-up, and 71 (89%) of 80 patients had complete data on patient-reported outcomes. Bohm et al (2016) was an unblinded, multicenter RCT conducted in Germany and also sponsored by the device manufacturer.93 One thousand two patients with NYHA class II or III heart failure and an LVEF of 35% or less were randomized to have their ICD or CRT-D devices automatically transmit fluid index telemedicine alerts or not. Alerts were triggered by intrathoracic fluid index threshold crossing, which was programmed at the investigator’s discretion. Patients were followed for a mean of 1.9 years. All patients were included in the intention-to-treat Cox proportional hazard analyses.
None of the 3 RCTs reported improvements for the remote monitoring group on any outcome measures (see Table 7). In the Domenichini study, there were no significant differences reported between groups for hospitalizations rates, functional status, or QOL. Luthje reported no differences in mortality or hospitalizations. Also, Luthje reported a HR for time to the first hospitalization that was not significant at 1.23 (95% CI, 0.62 to 2.44, p=0.55). Mean number of emergency department visits did not differ between the remote monitoring group (0.10) and the usual care group (0.10; p=0.73), but the mean number of urgent care visits was higher for remote monitoring (0.30) than for usual care (0.10; p=0.03). Bohm reported no differences in the composite outcome of all-cause death and cardiovascular hospitalization (HR=0.87; 95% CI, 0.72 to 1.04) or mortality (HR=0.89; 95% CI, 0.62 to 1.28).

Table 7. Randomized Controlled Trials of Remote Monitoring With Combined Cardiac Resynchronization Therapy and Fluid Monitoring Device

<table>
<thead>
<tr>
<th>Study</th>
<th>N</th>
<th>Group</th>
<th>Outcomes</th>
<th>Mortality</th>
<th>Hospitalizations</th>
<th>6MWT</th>
<th>MLHFQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bohm et al</td>
<td>1002</td>
<td>Remote fluid monitoring</td>
<td></td>
<td>11.7%</td>
<td>21%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2016)</td>
<td></td>
<td>Usual care</td>
<td></td>
<td>12.7%</td>
<td>25%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domenichini et al</td>
<td>80</td>
<td>Remote fluid monitoring</td>
<td></td>
<td>0.3 (SD=0.9) per patient a</td>
<td>+1.5 m</td>
<td>-3 points</td>
<td></td>
</tr>
<tr>
<td>(2016)</td>
<td></td>
<td>Usual care</td>
<td></td>
<td>0.2 (SD=0.4) per patient</td>
<td>-53.5 m</td>
<td>+10 points</td>
<td></td>
</tr>
<tr>
<td>Luthje et al</td>
<td>176</td>
<td>Remote fluid monitoring</td>
<td></td>
<td>8.6% a</td>
<td>27% (20/73)</td>
<td>0.83</td>
<td>0.07</td>
</tr>
<tr>
<td>(2015)</td>
<td></td>
<td>Usual care</td>
<td></td>
<td>4.6%</td>
<td>27% (22/82)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>p</td>
<td></td>
<td></td>
<td></td>
<td>0.95</td>
<td>NR</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MLHFQ: Minnesota Living with Heart Failure Questionnaire; NR: not reported; 6MWT: 6-minute walk test.

a Kaplan-Meier estimate of 1-year mortality rate.
b Total hospitalizations per patient over study period.

Section Summary: CRT Combined With Remote Fluid Monitoring

Three RCTs have reported no improvements in outcomes associated with remote fluid monitoring for patients with heart failure. These RCTs do not support a benefit from remote monitoring of fluid status vs usual care.

Summary of Evidence

For individuals who have NYHA class III or IV heart failure with a left ventricular ejection fraction of 35% or less who are in sinus rhythm, treated with guideline-directed medical therapy, and have either LBBB or a QRS interval of 150 ms or more who receive CRT with or without defibrillator, the evidence includes RCTs and systematic reviews of RCTs. Relevant outcomes are overall survival, symptoms, functional outcomes, quality of life, hospitalizations, and treatment-related morbidity. There is a large body of clinical trial evidence supporting the use of CRT in patients with NYHA class III or IV heart failure. The RCTs have consistently reported that CRT reduces mortality, improves functional status, and improves quality of life for patients with NYHA class III or IV heart failure. Multiple subgroup analyses of RCTs have demonstrated that the benefit of CRT is mainly
restricted to patients with LBBB or QRS interval greater than 150 ms. The evidence is sufficient to determine that the technology results in a meaningful improvement in the net health outcome.

For individuals who have NYHA class II heart failure with a left ventricular ejection fraction of 30% or less who are in sinus rhythm, treated with guideline-directed medical therapy, and have either LBBB or a QRS interval of 150 ms or more who receive CRT with or without defibrillator, the evidence includes RCTs and systematic reviews of RCTs. Relevant outcomes are overall survival, symptoms, functional outcomes, quality of life, hospitalizations, and treatment-related morbidity. For patients with NYHA class II heart failure, at least 4 RCTs assessing CRT have been published. A mortality benefit was reported in 1 of the 4 trials, the Resynchronization-Defibrillation for Ambulatory Heart Failure Trial. None of the other 3 RCTs reported a mortality difference, but a subgroup analysis of the MADIT-CRT trial reported a mortality benefit for patients with LBBB. Among other outcome measures, hospitalizations for heart failure showed consistent reductions, but quality of life and functional status did not improve. Multiple subgroup analyses of RCTs have demonstrated that the benefit of CRT is mainly restricted to patients with LBBB or a QRS interval greater than 150 ms. The evidence is sufficient to determine that the technology results in a meaningful improvement in the net health outcome.

For individuals who have NYHA class I heart failure who receive CRT with or without defibrillator, the evidence includes RCTs and systematic reviews of RCTs. Relevant outcomes are overall survival, symptoms, functional outcomes, quality of life, hospitalizations, and treatment-related morbidity. Few patients with NYHA class I heart failure have been included in RCTs. The MADIT-CRT trial included 265 patients with class I. While the treatment effect on death and hospitalization favored combined implantable cardiac defibrillator plus CRT devices vs implantable cardiac defibrillator alone for class I patients, the confidence interval was large and included a 25% to 30% increase in events. The evidence is insufficient to determine the effects of the technology on health outcomes.

For individuals who have heart failure and atrial fibrillation who receive CRT with or without defibrillator, the evidence includes 4 RCTs and observational studies. Relevant outcomes are overall survival, symptoms, functional outcomes, quality of life, hospitalizations, and treatment-related morbidity. Results from RCTs have been conflicting, with one reporting improvements for patients with atrial fibrillation and others reporting no significant improvements. Results from observational studies are also conflicting. The evidence is insufficient to determine the effects of the technology on health outcomes.

For individuals who have heart failure and atrioventricular nodal block who receive CRT, the evidence includes RCTs and systematic reviews of RCTs. Relevant outcomes are overall survival, symptoms, functional outcomes, quality of life, hospitalizations, and treatment-related morbidity. One large RCT demonstrated that CRT led to reductions in heart failure–related hospitalizations and urgent care visits among patients with heart failure and atrioventricular block but who would
not necessarily meet conventional criteria for CRT. For patients who require ventricular pacing but have no left ventricular dysfunction, results of a small RCT have suggested that biventricular pacing is associated with improvement in cardiac function, but the trial was small and underpowered to detect differences in clinical outcomes. The evidence is sufficient to determine that the technology results in a meaningful improvement in the net health outcome.

For individuals who have heart failure who receive triple-site CRT, the evidence includes small RCTs and a meta-analysis that included nonrandomized studies. Relevant outcomes are overall survival, symptoms, functional outcomes, quality of life, hospitalizations, and treatment-related morbidity. The available RCTs have reported improved outcomes on at least 1 measure of functional status or quality of life with triple-site CRT compared with conventional CRT. However, the trials were small and had methodologic limitations. Also, outcomes reported differed across studies. Triple-site CRT was also associated with higher radiation exposure and a greater number of additional procedures postimplantation. Larger, high-quality RCTs are needed to define better the benefit-risk ratio for triple-site CRT compared with conventional CRT. The evidence is insufficient to determine the effects of the technology on health outcomes.

For individuals who have heart failure who receive CRT combined with remote fluid monitoring, the evidence includes 3 RCTs. Relevant outcomes are overall survival, symptoms, functional outcomes, quality of life, hospitalizations, and treatment-related morbidity. Three RCTs have reported no improvement in outcomes associated with remote fluid monitoring for patients with heart failure. The evidence is insufficient to determine the effects of the technology on health outcomes.

**Supplemental Information**

**Clinical Input From Physician Specialty Societies and Academic Medical Centers**

While the various physician specialty societies and academic medical centers may collaborate with and make recommendations during this process, through the provision of appropriate reviewers, input received does not represent an endorsement or position statement by the physician specialty societies or academic medical centers, unless otherwise noted.

In response to requests, input was received from 1 physician specialty society and 8 academic medical centers while this policy was under review in 2012. There was consensus with the medically necessary statements. For patients with class I heart failure, there was mixed input as to whether cardiac resynchronization therapy should be medically necessary. Regarding the duration of the QRS complex, commentators acknowledged that the literature supported use mainly in patients with a QRS interval greater than 150 ms, but most reviewers disagreed with restricting cardiac resynchronization therapy use to patients in that group because that duration was not currently the accepted standard of care. For patients with
atrial fibrillation, the input was mixed on whether biventricular pacing improves outcomes.

**Practice Guidelines and Position Statements**

**American College of Cardiology et al**
In 2013, the American College of Cardiology Foundation and American Heart Association published joint guidelines for the management of heart failure. These guidelines made recommendations on cardiac resynchronization therapy (CRT) for heart failure that are in line with those made by the American College of Cardiology Foundation, American Heart Association, and Heart Rhythm Society related to CRT for heart failure outlined next.

A focused update to 2008 guidelines for device-based treatment of cardiac rhythm abnormalities was published jointly by American College of Cardiology Foundation, American Heart Association, and Heart Rhythm Society in 2012. These guidelines included the following recommendations on CRT for heart failure (see Table 8).

**Table 8. Joint Guidelines on Treatment of Cardiac Rhythm Abnormalities**

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>COR</th>
<th>LOE</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRT is indicated for patients who have LVEF less than or equal to 35%, sinus rhythm, LBBB with a QRS duration greater than or equal to 150 ms, and NYHA class II, III, or ambulatory IV symptoms on GDMT</td>
<td>I</td>
<td>Aa</td>
</tr>
<tr>
<td>CRT can be useful for patients who have LVEF less than or equal to 35%, sinus rhythm, LBBB with a QRS duration 120 to 149 ms, and NYHA class II, III, or ambulatory IV symptoms on GDMT</td>
<td>IIa</td>
<td>B</td>
</tr>
<tr>
<td>CRT can be useful for patients who have LVEF less than or equal to 35%, sinus rhythm, a non-LBBB pattern with a QRS duration greater than or equal to 150 ms, and NYHA class III/ambulatory class IV symptoms on GDMT</td>
<td>IIa</td>
<td>A</td>
</tr>
<tr>
<td>CRT can be useful in patients with atrial fibrillation and LVEF less than or equal to 35% on GDMT if a) 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</td>
<td>IIa</td>
<td>B</td>
</tr>
<tr>
<td>CRT can be useful for patients on GDMT who have LVEF less than or equal to 35% and are undergoing new or replacement device placement with anticipated requirement for significant (&gt;40%) ventricular pacing</td>
<td>IIa</td>
<td>C</td>
</tr>
<tr>
<td>CRT may be considered for patients who have LVEF less than or equal to 30%, ischemic etiology of heart failure, sinus rhythm, LBBB with a QRS duration of greater than or equal to 150 ms, and NYHA class I symptoms on GDMT</td>
<td>IIb</td>
<td>C</td>
</tr>
<tr>
<td>CRT may be considered for patients who have LVEF less than or equal to 35%, sinus rhythm, a non-LBBB pattern with QRS duration 120 to 149 ms, and NYHA class III/ambulatory class IV on GDMT</td>
<td>IIb</td>
<td>B</td>
</tr>
<tr>
<td>CRT may be considered for patients who have LVEF less than or equal to 35%, sinus rhythm, a non-LBBB pattern with a QRS duration greater than or equal to 150 ms, and NYHA class II symptoms on GDMT</td>
<td>IIb</td>
<td>B</td>
</tr>
<tr>
<td>CRT is not recommended for patients with NYHA class I or II symptoms and non-LBBB pattern with QRS duration less than 150 ms</td>
<td>IIIc</td>
<td>B</td>
</tr>
<tr>
<td>CRT is not indicated for patients whose comorbidities and/or frailty limit survival with good functional capacity to less than 1 year</td>
<td>IIIc</td>
<td>C</td>
</tr>
</tbody>
</table>

AV: atrioventricular; COR: class of recommendation; CRT: cardiac resynchronization therapy; GDMT: guideline-directed medical therapy; LBBB: left bundle branch block; LOE: level of evidence; LVEF: left ventricular ejection fraction; NYHA: New York Heart Association.
a For NYHA class III or IV heart failure.
b For NYHA class II heart failure.
c No benefit.

European Society of Cardiology and European Heart Rhythm Association
The European Society of Cardiology and the European Heart Rhythm Association released guidelines on cardiac pacing and CRT in 2013.\textsuperscript{97} These guidelines included the following recommendations on CRT for heart failure with sinus rhythm (see Table 9).

Table 9. Joint Guidelines on Cardiac Pacing and CRT

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>COR</th>
<th>LOE</th>
</tr>
</thead>
<tbody>
<tr>
<td>LBBB with QRS duration greater than 150 ms. CRT is recommended in chronic heart failure patients and LVEF less than or equal to 35% who remain in NYHA functional class II, III, and ambulatory IV despite adequate medical treatment</td>
<td>I</td>
<td>A</td>
</tr>
<tr>
<td>LBBB with QRS duration from 120 to 150 ms. CRT is recommended in chronic heart failure patients and LVEF less than or equal to 35% who remain in NYHA functional class II, III, and ambulatory IV despite adequate medical treatment</td>
<td>I</td>
<td>B</td>
</tr>
<tr>
<td>Non-LBBB with QRS duration greater than 150 ms. CRT should be considered in chronic heart failure patients and LVEF less than or equal to 35% who remain in NYHA functional class II, III, and ambulatory IV despite adequate medical treatment</td>
<td>IIa</td>
<td>B</td>
</tr>
<tr>
<td>Non-LBBB with QRS duration 120-150 ms. CRT may be considered in chronic heart failure patients and LVEF less than or equal to 35% who remain in NYHA functional class II, III, and ambulatory IV despite adequate medical treatment</td>
<td>IIb</td>
<td>B</td>
</tr>
<tr>
<td>CRT in patients with chronic heart failure with QRS duration less than 120 ms is not recommended</td>
<td>III\textsuperscript{a}</td>
<td>B</td>
</tr>
</tbody>
</table>

COR: class of recommendation; CRT: cardiac resynchronization therapy; LBBB: left bundle branch block; LOE: level of evidence; LVEF: left ventricular ejection fraction; NYHA: New York Heart Association.

\textsuperscript{a} No benefit.

Heart Failure Society of America
The Heart Failure Society of America (2010) released comprehensive guidelines on the management of heart failure.\textsuperscript{98} The guidelines included the following recommendations on the use of CRT (see Table 10).

Table 10. Guidelines on Management of Heart Failure

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>LOE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biventricular pacing therapy is recommended for patients in sinus rhythm with a widened QRS interval (≥120 ms) and severe LV systolic dysfunction (LVEF ≤35%) who have persistent, moderate to severe HF (NYHA III) despite optimal medical therapy.</td>
<td>A</td>
</tr>
<tr>
<td>Biventricular pacing therapy may be considered for patients with atrial fibrillation with a widened QRS interval (≥120 ms) and severe LV systolic dysfunction LVEF ≤35% who have persistent, moderate to severe HF (NYHA III) despite optimal medical therapy.</td>
<td>B</td>
</tr>
<tr>
<td>Selected ambulatory NYHA IV patients in sinus rhythm with QRS ≥120 ms and LV systolic dysfunction may be considered for biventricular pacing therapy.</td>
<td>B</td>
</tr>
<tr>
<td>Biventricular pacing therapy may be considered in patients with reduced LVEF and QRS ≥ 150 ms who have NYHA I or II HF symptoms.</td>
<td>B</td>
</tr>
<tr>
<td>In patients with reduced LVEF who require chronic pacing and in whom frequent ventricular pacing is expected, biventricular pacing may be considered.</td>
<td>C</td>
</tr>
</tbody>
</table>

HF: heart failure; LOE: level of evidence; LV: left ventricular; LVEF: left ventricular ejection fraction; NYHA: New York Heart Association.
National Institute for Health and Care Excellence
The National Institute for Health and Care Excellence’s 2014 guidance provided recommendations on CRT for heart failure. The recommendations for patients with left ventricular ejection fraction of 35% or less are list in Table 11.

Table 11. Guidelines on Management of Cardiac Resynchronization Therapy for Heart Failure

<table>
<thead>
<tr>
<th>Indication</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>NYHA class I-IV with QRS interval &lt; 120 ms</td>
<td>CRT not recommended</td>
</tr>
<tr>
<td>NYHA class IV with QRS interval 120 to 149 ms and without LBBB</td>
<td>CRT-P recommended</td>
</tr>
<tr>
<td>NYHA class II-III with QRS interval 120 to 149 ms and with LBBB</td>
<td>CRT-D recommended</td>
</tr>
<tr>
<td>NYHA class III-IV with QRS interval 120 to 149 ms and with LBBB</td>
<td>CRT-P recommended</td>
</tr>
<tr>
<td>NYHA class I-III with QRS interval ≥ 150 ms (with or without LBBB)</td>
<td>CRT-D recommended</td>
</tr>
<tr>
<td>NYHA class III-IV with QRS interval ≥ 150 ms (with or without LBBB)</td>
<td>CRT-P recommended</td>
</tr>
</tbody>
</table>

CRT-D: cardiac resynchronization therapy with implantable cardiac defibrillator; CRT-P: cardiac resynchronization therapy with pacemaker; LBBB: left bundle branch block; NYHA: New York Heart Association.

U.S. Preventive Services Task Force Recommendations
Not applicable.

Medicare National Coverage
There is no national coverage determination. In the absence of a national coverage determination, coverage decisions are left to the discretion of local Medicare carriers.

Ongoing and Unpublished Clinical Trials
Some currently unpublished trials that might influence this review are listed in Table 12.

Table 12. Summary of Key Active Trials

<table>
<thead>
<tr>
<th>NCT No.</th>
<th>Trial Name</th>
<th>Planned Enrollment</th>
<th>Completion Date</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ongoing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NCT02454439</td>
<td>Assessment of Cardiac Resynchronization Therapy in Patients With Wide QRS and Non-specific Intraventricular Conduction Delay: a Randomized Trial</td>
<td>200</td>
<td>Nov 2018</td>
</tr>
<tr>
<td>NCT01994252</td>
<td>Resynchronization/Defibrillation for Ambulatory Heart Failure Trial in Patients With Permanent Atrial Fibrillation (RAFT-PermAF)</td>
<td>950</td>
<td>Dec 2018</td>
</tr>
<tr>
<td>NCT02137187</td>
<td>A Randomized Controlled Trial of Atrioventricular (AV) Junction Ablation and Biventricular Pacing Versus Optimal Pharmacological Therapy in Patients With Permanent Atrial Fibrillation</td>
<td>1830</td>
<td>May 2019</td>
</tr>
<tr>
<td>NCT02962791</td>
<td>Prospective Randomized Trial Comparing TRIPLE Site ventricular Stimulation Versus Conventional Pacing in CRT canDidates: TRIPLEAD Trial</td>
<td>166</td>
<td>May 2020</td>
</tr>
<tr>
<td>NCT02922036</td>
<td>Stimulation Of the Left Ventricular Endocardium for Cardiac Resynchronization Therapy in Non-Responders and Previously Untreatable Patients (SOLVE CRT)</td>
<td>350</td>
<td>Sep 2020</td>
</tr>
<tr>
<td>NCT01522898a</td>
<td>Cardiac Resynchronisation Therapy and AV Nodal</td>
<td>590</td>
<td>Jan 2022</td>
</tr>
<tr>
<td>NCT No.</td>
<td>Trial Name</td>
<td>Planned Enrollment</td>
<td>Completion Date</td>
</tr>
<tr>
<td>--------------</td>
<td>----------------------------------------------------------------------------</td>
<td>--------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>Unpublished</td>
<td>Ablation Trial in Atrial Fibrillation (CAAN-AF)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NCT00187278</td>
<td>Biventricular Pacing for Atroventricular Block in Left Venticular Dysfunction to Prevent Cardiac Desynchronization</td>
<td>1833</td>
<td>Oct 2014 (completed)</td>
</tr>
</tbody>
</table>

NCT: national clinical trial.

a Denotes industry-sponsored or cosponsored trial.

References


34. Rao RK, Kumar UN, Schafer J, et al. Reduced ventricular volumes and improved systolic function with cardiac resynchronization therapy: a randomized trial comparing simultaneous biventricular pacing, sequential biventricular pacing, and left ventricular pacing. Circulation. Apr 24 2007;115(16):2136-2144. PMID 17420340

**Billing Coding/Physician Documentation Information**

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<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>33221</td>
<td>Insertion of pacemaker pulse generator only; with existing multiple leads</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 pacing cardioverter-defibrillator pulse generator (including revision of pocket, removal, insertion and/or replacement of generator)</td>
</tr>
</tbody>
</table>
33225  Insertion of pacing electrode, cardiac venous system, for left ventricular pacing, at time of insertion of pacing cardioverter-defibrillator or pacemaker pulse generator (including upgrade to dual chamber system) (List separately in addition to code for primary procedure)

33228  Removal of permanent pacemaker pulse generator with replacement of pacemaker pulse generator; dual lead system

33233  Removal of permanent pacemaker pulse generator only

ICD-10 Codes

I50.20-  Congestive heart failure, code range,
I50.9

In 2003, CPT introduced separate codes for biventricular pacing. Note that CPT “dual chamber” codes describe combined right atrial and right ventricular electrode placement. CPT “biventricular” codes describe the additional placement of a left ventricular electrode via the cardiac vein. A left ventricular pacing lead is placed in the marginal branch of the coronary sinus and into a cardiac vein to allow for biventricular pacing for cardiac resynchronization. CPT notes the following:

“A single chamber pacemaker system includes a pulse generator and one electrode inserted in either the atrium or the ventricle. A dual chamber pacemaker system includes a pulse generator and one electrode inserted in the right atrium and one electrode inserted in the right ventricle. In certain circumstances, an additional electrode may be required to achieve pacing of the left ventricle (biventricular pacing). In this event, transvenous cardiac vein placement of the electrode should be separately reported using code 33224 or 33225.”

- 33224 Insertion of pacing electrode, cardiac venous system, for ventricular pacing, with attachment to previously placed pacemaker or pacing cardioverter-defibrillator pulse generator (including revision of pocket, removal, insertion, and/or replacement of generator).
- 33225 Insertion of pacing electrode, cardiac venous system, for left ventricular pacing, at time of insertion of pacing cardioverter-defibrillator or pacemaker pulse generator (including upgrade to dual chamber system (list separately in addition to code for primary procedures).

Use 33225 in conjunction with 33206, 33207, 33208, 33212, 33213, 33214, 33216, 33217, 33221, 33223, 33228, 33229, 33230, 33231, 33233, 33234, 33235, 33240, 33249, 33263, and 33264.

Thus, CPT describes 33225 as an “add-on” code to other pacing or pacing cardioverter-defibrillator procedures.

Additional Policy Key Words

N/A

Policy Implementation/Update Information
8/1/05  New policy.
8/1/06  Policy revised; policy statement indicates that intrathoracic bioimpedance is considered investigational as a component of a biventricular pacemaker; patient selection criteria for combined biventricular pacemaker/AICD revised to indicate that a combined device would be considered medically necessary in patients who meet the criteria for a biventricular pacemaker alone.
8/1/07  No policy statement changes.
8/1/08  No policy statement changes.
8/1/09  No policy statement changes.
8/1/10  New policy statement added that use in patients with class I/II heart failure is investigational. Sinus rhythm added to the list of criteria needed for the medically necessary policy statement; intent of the policy statement otherwise unchanged.
8/1/11  Policy statement updated related to mild heart failure. CRT use in patients with NYHA class II heart failure meeting specific criteria now may be considered medically necessary; all other uses in mild heart failure (e.g., class I) considered investigational. Term “congestive” removed from title and text.
1/1/12  Coding updated
8/1/12  Policy statement revised to remove “(or angiotensin receptor blocker)” from the fourth bullet after beta blocker in both of the NYHA criteria lists in the first policy statement. “Cardiac Resynchronization Therapy” added to policy title.
8/1/13  Additional investigational policy statements added for triple-site (triventricular) CRT and cardiac resynchronization as a treatment of heart failure in patients with atrial fibrillation.
8/1/14  No policy statement changes.
8/1/15  Policy statements for CRT in class II and II/IV heart failure changed to include presence of LBBB (and QRS >120–130 ms) OR QRS >150 ms as medically necessary criteria. Policy statement added that CRT in patients with heart failure and AV block may be considered medically necessary with criteria.
8/1/16  Removed QRS duration of ≥120–130* msec, from Medically Necessary statement. No other policy statement changes.
8/1/17  No policy statement changes.
8/1/18  Policy statement added that cardiac resynchronization therapy with wireless left ventricular endocardial pacing is considered investigational.

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