

2022 HRS/APHRS/LAHS Guideline on Cardiac Physiologic Pacing for the Avoidance and Mitigation of Heart Failure

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Definitions, Epidemiology, and Pathophysiology

COR	LOE	Recommendations	References
Epidemiology of Electrical Dyssynchrony-Induced Cardiomyopathy			
1	B-NR	1. In patients who have substantial RV pacing that cannot be minimized with programming, periodic assessment of ventricular function is recommended to detect pacing-induced cardiomyopathy.	1-7
2a	B-NR	2. In patients with chronic LBBB, periodic assessment of ventricular function is reasonable to detect cardiomyopathy.	8-14

Indications for CPP - Pacemaker Indicated Patients

COR	LOE	Recommendations	References
Normal EFs vs. EFs 36-50% and Substantial (> 20-40%) vs. Not Substantial (< 20-40%) Anticipated Pacing Requirements			
2b	B-NR	3. In patients with normal LVEF who are anticipated to have substantial ventricular pacing, it may be reasonable to treat patients with CPP (CRT, HBP, LBBAP) to reduce risk of pacing-induced cardiomyopathy.	2, 4, 15-26
3 No Benefit	B-R	4. In patients with normal LVEF who are not anticipated to have substantial ventricular pacing, CRT with BiV pacing is not indicated	2, 16, 23-28
2a	B-R	5. In patients with an indication for permanent pacing with LVEF 36-50% and expected to require less than substantial ventricular pacing, it is reasonable to choose a traditional RV lead and minimize RV pacing.	2, 15, 22
2b	C-LD	6. In patients with an indication for permanent pacing with LVEF 36-50% and expected to require less than substantial ventricular pacing, CSP with HBP or LBBAP may be considered.	15, 22
2a	B-R (CRT) B-NR (CSP)	7. In patients with an indication for permanent pacing with a LVEF 36-50% who are expected to require substantial ventricular pacing, CPP (CRT, HBP, LBBAP) is reasonable to reduce risk of pacing-induced cardiomyopathy.	<u>CRT</u> 16, 23, 24, 29-33 <u>HBP</u> 4, 15, 19, 21, 32-35 <u>LBBAP</u> 36-39

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2b	C-EO	8. In patients who are pacemaker dependent undergoing HBP pacemaker implantation, placement of an additional “backup” lead may be reasonable.	
Expected Less Than Substantial Ventricular Pacing, LVEF 36-50%, and LBBB			
2b	C-LD	9. In patients for whom a pacemaker is indicated, with expected less than substantial ventricular pacing, and with LVEF between 36-50% and left bundle branch block, CPP (CRT, HBP, LBBAP) may be considered.	<u>CRT</u> 40, 41 <u>HBP</u> 12, 42 <u>LBBAP</u> 22, 36, 42-44
At Time of Surgery			
2a	B-R	10. In patients undergoing cardiac surgery who will likely require future CRT, intraoperative placement of a permanent epicardial LV lead can be useful.	45-47
2b	C-EO	11. In patients undergoing cardiac surgery who will likely require substantial ventricular pacing, intraoperative placement of a permanent epicardial LV lead may be considered.	

Indications for CPP - Without Bradycardia Pacing Indications

COR	LOE	Recommendations	References
LBBB, QRS\geq150 ms, NYHA II/III/IV			
1	A	12. In patients with LVEF less than or equal to 35%, sinus rhythm, LBBB with a QRS duration \geq 150 ms, and NYHA class II, III or ambulatory IV symptoms on GDMT, CRT with BiV pacing is indicated in order to improve symptoms and reduce morbidity and mortality.	48-57
2a	C-LD	13. In patients with LVEF \leq 35%, sinus rhythm, LBBB with a QRS duration \geq 150 ms, and NYHA class II, III or ambulatory IV symptoms on GDMT, CSP with HBP or LBBAP is reasonable if CRT cannot be achieved with BiV pacing when the CS LV lead location is suboptimal based on anatomical or functional criteria.	<u>HBP</u> 58-64 <u>LBBAP</u> 11, 36, 38, 42, 44
2b	C-LD	14. In patients who require or are candidates for a CIED but do not have an indication for ventricular pacing, with LVEF 36-50%, sinus rhythm, LBBB with a QRS duration \geq 150 ms, and NYHA class II, III or ambulatory IV symptoms on GDMT, CPP (CRT, HBP, LBBAP) may be considered to maintain or improve LVEF.	<u>CRT</u> 40, 65-67 <u>HBP</u> 58-64 <u>LBBAP</u> 11, 36, 38, 42, 44

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2b	C-LD	15. In patients with LVEF \leq 35%, sinus rhythm, LBBB with a QRS duration \geq 150 ms, and NYHA class II, III or ambulatory IV symptoms on GDMT, CSP with HBP or LBBAP may be considered as an alternative to CRT with BiV pacing.	<u>HBP</u> 58-64 <u>LBBAP</u> 11, 36, 38, 42, 44
LBBB, QRS Duration 120-149 ms, NYHA II, III, IV			
1	A	16. In female patients who have LVEF \leq 35%, sinus rhythm, LBBB with a QRS duration 120 to 149 ms, and NYHA class II, III, or ambulatory IV symptoms on GDMT, CRT with BiV pacing is recommended.	50-52, 54-56, 68-77
2a	B-R	17. In patients who have LVEF \leq 35%, sinus rhythm, LBBB with a QRS duration 120 to 149 ms, and NYHA class II, III, or ambulatory IV symptoms on GDMT, CRT with BiV pacing can be useful.	50-52, 54-56, 68, 69
3 No benefit	B-R	18. In patients with LVEF \leq 35%, NYHA class II, III, or ambulatory IV symptoms on GDMT, and QRS duration $<$ 120 ms, CRT with BiV pacing is not recommended.	78-81
Non-LBBB QRS \geq150ms, NYHA II/III/IV			
2a	A	19. In patients who have LVEF less than or equal to 35%, sinus rhythm, a non-LBBB pattern with a QRS duration \geq 150 ms, and NYHA class III/ ambulatory class IV symptoms on GDMT, CRT with BiV pacing can be useful.	50, 51, 56, 82
2b	B-R (CRT) C-LD (CSP)	20. In patients who have LVEF \leq 35%, sinus rhythm, a non-LBBB pattern with a QRS duration \geq 150 ms, and NYHA class II symptoms on GDMT, CPP (CRT, HBP, LBBAP) may be considered.	<u>CRT</u> 54, 56 <u>CSP</u> 38, 61
2b	C-LD	21. In patients with LVEF \leq 35%, sinus rhythm, non-LBBB with a QRS duration $>$ 150 ms, and NYHA class II, III or ambulatory IV symptoms on GDMT, CSP with HBP or LBBAP pacing may be reasonable if CRT cannot be achieved with BiV pacing based on anatomical or functional criteria.	34, 38, 61, 83

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With High Burden Right Ventricular Pacing			
2a	B-NR	22. In patients with a cardiac implantable electronic device, LVEF <50%, and a decline in LV function or worsening of heart failure symptoms (NYHA class II-IV) attributed to substantial ventricular pacing, revision to CPP (CRT, HBP, LBBAP) can be beneficial to improve LV function and symptoms of heart failure.	2, 7, 84-87
1	C-LD	23. In patents with cardiac implantable electronic device, LVEF ≤35%, and a decline in LV function or worsening of heart failure symptoms attributed to substantial ventricular pacing, CRT with BiV pacing is recommended to improve LV function and to reduce rates of death and hospitalization for heart failure.	56
LBBB QRS ≥150ms, NYHA I			
2b	B-R	24. In patients with cardiomyopathy with LVEF ≤ 30%, LBBB, QRS ≥ 150 ms and NYHA class I heart failure, CRT with BiV pacing may be considered.	52, 54, 88
Non-LBBB QRS 120-149 ms, NYHA III/IV			
2b	B-NR (CRT) C-LD (CSP)	25. In patients who have LVEF ≤35%, sinus rhythm, a non-LBBB pattern with QRS duration 120 to 149 ms, and NYHA class III/ambulatory class IV on GDMT, CPP (CRT, HBP, LBBAP) may be considered.	<u>CRT</u> 54, 56, 89 <u>CSP</u> 34, 37, 38, 61
Non-LBBB QRS <150 ms, NYHA I, II			
3 No Benefit	B-R	26. In patients who have LVEF ≤ 35%, sinus rhythm, a non-LBBB pattern with a QRS duration < 150 ms, and NYHA class I or II symptoms on GDMT, CRT with BiV pacing is not recommended.	54, 56, 90
Survival < 1 Year			
1	C-EO	27. In patients with a life expectancy of < 1 year, the decision to implant CPP (CRT, HBP, LBBAP) should incorporate shared decision-making, taking into account the potential improvement in quality of life balanced against the risk of procedural complications.	

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Indications for CPP – In Atrial Fibrillation

COR	LOE	Recommendations	References
2a	B-NR	28. In patients with AF who otherwise meet CRT implantation eligibility criteria, CRT with BiV pacing can be beneficial.	29, 91-94
2a	B-R	29. In patients with treatment refractory AF undergoing AV junction ablation with LVEF \leq 50%, CRT with BiV pacing is reasonable to improve clinical outcomes.	29, 95-100
2b	C-LD	30. In patients with treatment refractory AF undergoing AV junction ablation, HBP with or without a backup RV pacing may be reasonable.	33, 101-106
2b	C-LD	31. In patients with treatment refractory AF undergoing AV junction ablation, it may be reasonable to implant a LBBAP lead.	83, 106, 107

Preprocedure Evaluation, Preparation

COR	LOE	Recommendations	References
Role of ECG and Monitoring in Determining Type of CPP			
1	A	32. In patients with indications for pacing, a 12-lead ECG is recommended to evaluate rhythm, rate, AV conduction, QRS duration and morphology in order to determine the appropriate type of CPP (CRT, HBP, LBBAP).	108-115
Pre-Procedure Imaging			
1	A (CRT) C-EO (CSP)	33. In patients planned to undergo implantation of a CPP device, pre-procedural echocardiographic screening for LVEF is recommended.	52, 54, 56
2b	B-R	34. In patients indicated for CRT, use of an imaging modality (e.g., echo, cMRI, or CT) may be considered to target LV lead placement.	116-120
3 No Benefit	A	35. In patients being considered for CRT, pre-procedural echocardiographic assessment of ventricular dyssynchrony is not useful to predict outcomes from CRT with BiV pacing.	121, 122

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Shared Decision-Making During Pre-Procedural Planning		
1	C-EO	36. In patients who may benefit from CPP (CRT, HBP, LBBAP), clinicians and patients should engage in a shared decision-making approach in which 1) information is shared on the evidence base for different types of CPP and 2) treatment decisions are based not only on the best available evidence, but also on the patient’s goals of care, preferences, and values.

Implant Procedure

COR	LOE	Recommendations	References
Tools and Techniques for CRT with BiV Pacing			
1	B-R	37. In patients undergoing CRT implant, a quadripolar LV lead is recommended to assist with lead stability, lower capture thresholds, avoid phrenic nerve pacing, and decrease need for lead re-positioning.	32, 123-126
2a	C-LD	38. In patients undergoing CRT implant, lead positioning and programming the device to provide the narrowest QRS can be beneficial in improving LV structure and function.	127-130
2a	C-LD	39. In patients undergoing CRT implant, LV lead placement to allow for pacing from a non-apical position is reasonable.	131-134
2b	C-LD	40. In patients undergoing CRT implant, targeting lead placement at sites of late ventricular activation may be considered to improve CRT response.	135-142
Tools and Techniques for CSP with HBP or LBBP			
1	C-EO	41. In patients undergoing CSP with HBP or LBBAP, twelve lead ECG is useful during implantation to most accurately assess conduction system capture.	
1	C-EO	42. In patients undergoing CSP with HBP or LBBAP, accurate demonstration of conduction system capture thresholds (including BBB correction) and myocardial capture thresholds at implant is useful for appropriate programming of the device.	
2a	C-LD	43. In patients undergoing CSP with HBP or LBBAP, assessment of His bundle/left bundle current of injury using appropriate filter settings can be beneficial in achieving acceptable capture thresholds and lead stability.	143-145

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When to Consider Alternative CPP Sites or Abandon CPP (Crossovers)			
2a	C-LD	44. In patients undergoing CRT with BiV pacing implantation via the coronary sinus, crossover to CSP with HBP or LBBAP is reasonable when the CS LV lead placement is unsuccessful or suboptimal.	34, 38, 42, 62, 64
2b	C-LD	45. In patients undergoing CRT with BiV pacing implantation via the coronary sinus, crossover to surgical epicardial CRT with BiV pacing might be reasonable when the initial approach is unsuccessful or suboptimal.	146-148

CPP Follow-up and Management

COR	LOE	Recommendations	References
Recommendations for Follow-Up Evaluation			
1	B-NR	46. After implantation of a CRT device in patients with HF _r EF, a follow up echocardiogram within 3 to 12 months is useful to determine reverse remodeling and the likelihood of improved survival and reduction in heart failure hospitalizations.	149-151
1	B-NR	47. In patients with CPP (CRT, HBP, LBBAP), remote monitoring is beneficial for device and arrhythmia management.	152-157
2a	B-NR (CRT) C-EO (CSP)	48. In patients with CPP (CRT, HBP, LBBAP) and heart failure, multidisciplinary management with heart failure and device clinics for adjustment of medications and device programming can be useful to improve clinical outcomes.	158-163
2a	C-LD	49. In patients with CRT and heart failure with improved ejection fraction (HF _{imp} EF), continuation of GDMT can be useful to reduce the risk of heart failure relapse and arrhythmias, and to treat hypertension.	164, 165
3 No Benefit	B-NR	50. In patients with CRT and HF _r EF, routine use of thoracic impedance alone to manage congestive heart failure is not recommended.	166-168

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Optimization of CRT and CSP Response			
1	C-EO	51. In patients with CRT, a 12 lead ECG is useful to confirm left ventricular lead capture.	
1	B-NR	52. During in-office follow-up of patients with CSP, a multi-lead or twelve lead ECG is recommended to assess conduction system capture, including bundle branch block correction.	4, 15, 21, 34, 37, 38, 59, 83, 169-178
2a	B-NR	53. During in-office follow up of patients with CSP, a comprehensive assessment that includes documentation of His/left bundle capture, bundle branch block correction, and myocardial capture thresholds can be useful.	4, 15, 21, 34, 37, 38, 59, 83, 169-178
2a	C-EO	54. In patients with HBP who have an increase in threshold of greater than 1V, more frequent in-office follow-up can be beneficial to determine the need for lead revision, especially in ventricular pacing dependent patients.	
Replacement or Upgrade Considerations			
1	C-LD	55. In patients with HFimpEF, continuation of CRT with BiV pacing is recommended at the time of elective generator replacement.	179, 180
1	C-EO	56. In patients who are thought to have benefited from CRT (including improvement, stabilization, or partial reversal of natural decline) in terms of symptoms, EF, or functional status, continuation of CRT with BiV pacing is recommended at the time of elective replacement based on patient-individualized risks and benefits of the procedure.	
1	B-NR	57. In patients with CRT-D at time of elective replacement, it is recommended that a decision for replacement versus revision to CRT-P should be based on patient-individualized risks and benefits of the procedure; and such shared decision making should involve consideration of the previous response to CRT, appropriate ICD therapies for ventricular arrhythmias, inappropriate therapies, current lead performance factors and the patient's overall goals of care.	181-184
2b	B-NR	58. In patients with a CRT-D and normalized LVEF who have received inappropriate therapies and have not had appropriate therapies, turning off defibrillator therapies may be considered after shared decision making with the patient.	181-184

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2b	C-EO	59. In patients with CRT or CSP where high lead pacing threshold contributes to rapid battery drain, implantation of a new lead may be considered after shared decision making with the patient at the time of generator replacement to reduce risk associated with frequent generator replacements.	
Troubleshooting Unfavorable CRT Response			
1	C-LD	60. In patients with HFrEF with unfavorable response to CRT with BiV pacing, continued efforts to optimize medical and device therapies are recommended to improve quality of life and long-term outcomes.	159, 163, 185
1	C-EO	61. In patients with an unfavorable response to CRT with BiV pacing, obtaining a PA and lateral chest X-Ray is recommended to assess left ventricular lead position.	
2a	C-LD	62. In patients with an unfavorable response to CRT with BiV pacing and who have less than optimal LV pacing percentage, ablation or pharmacological suppression of frequent PVCs, or better rhythm or rate control of atrial fibrillation is reasonable to improve cardiac function and patient symptoms.	186, 187
When to Cross Over to CSP, CRT, or Epicardial Options			
2a	C-LD (CSP) B-NR (Surgical Epicardial Lead)	63. In patients with unsuccessful CRT with BiV pacing, CSP with HBP or LBBAP, or surgical epicardial lead implantation can be useful when other approaches have been unsuccessful or not feasible.	<u>HBP</u> 60, 62, 64 <u>LBBAP</u> 38, 42, 188 <u>Surgical Epicardial Lead</u> 146, 148, 189, 190

Congenital Heart Disease and Pediatric Populations

COR	LOE	Recommendations	References
Congenital Heart Disease			
2b	C-LD	64. In patients with CHD on GDMT with a systemic EF <45% and ventricular dyssynchrony (as defined by a QRS duration Z score of ≥ 3 or ventricular pacing $\geq 40\%$), CRT with BiV pacing may be considered to reduce risk of mortality or need for transplant.	191-199
2b	C-LD	65. In patients with CHD and a systemic RV with symptomatic HF on GDMT, CRT with BiV pacing may be considered to improve or maintain functional class or ventricular function.	191-200

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2b	C-LD	66. In patients with CHD and a systemic single ventricle with symptomatic HF on GDMT, CRT with BiV pacing may be considered to maintain functional class or ventricular function.	191, 193, 201, 202
2b	C-LD	67. In patients with CHD and a subpulmonary right ventricle with right ventricular dysfunction and RBBB, CRT with BiV pacing may be considered to improve right ventricular function.	203-206
CRT for Heart Failure, Complete AVB in Pediatric Populations			
2a	C-LD	68. In pediatric patients with pre-existing ventricular pacing due to complete AVB, and symptomatic clinical heart failure on GDMT, permanent CRT with BiV pacing can be useful.	191, 193, 207, 208
2b	C-LD	69. In pediatric patients with complete AVB and evidence of clinical heart failure on GDMT, initial pacing based on achieving optimization of paced ventricular contractility with select site physiologic pacing or CRT with BiV pacing may be considered.	192
Select-Site Physiologic Pacing, Complete AVB in Pediatric Populations			
2a	C-LD	70. In pediatric patients meeting requirements for transvenous ventricular pacing, lead implant in the mid, inflow or para-His septum, to achieve CSP is reasonable without site-mapping, depending on acceptable pacing thresholds.	209-213
2a	C-LD	71. In pediatric patients meeting requirements for epicardial ventricular pacing, it is reasonable to choose LV epicardial pacing over RV epicardial pacing.	214-216

AF = atrial fibrillation; AVB = atrioventricular block; BiV = biventricular; CHD = congenital heart disease; cMRI = cardiac magnetic resonance imaging COR = Class of Recommendation; CPP = cardiac physiological pacing; CRT = cardiac resynchronization therapy; CRT-D = cardiac resynchronization therapy defibrillator; CRT-P = cardiac resynchronization therapy pacemaker; CSP = conduction system pacing; ECG = electrocardiogram; EF = ejection fraction; GDMT = guideline directed medical therapy; HBP = His bundle pacing; HCM = hypertrophic cardiomyopathy; HF = heart failure; HFimpEF = heart failure with improved ejection fraction; HFrEF = heart failure with reduced ejection fraction; ICD = implantable cardioverter defibrillator; LBBB = left bundle branch block; LBBAP = left bundle branch area pacing; LOE = level of evidence; LV = left ventricular; LVEF = left ventricular ejection fraction; NYHA = New York Hospital Association; RBBB = right bundle branch block; RV = right ventricular; V = volt; VT = ventricular tachycardia.

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