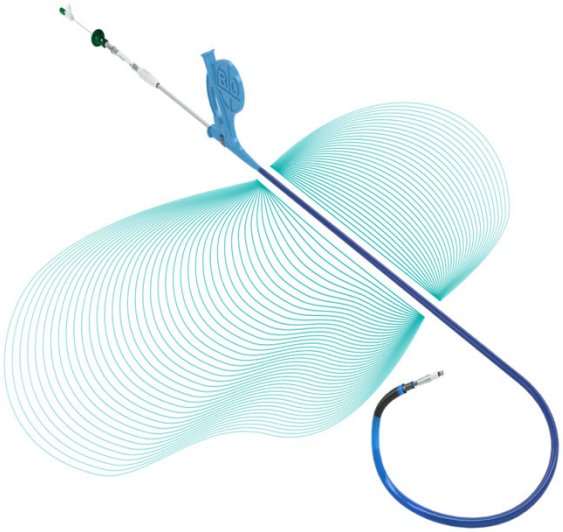

Physiologic Pacing Follow-up

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Objectives

Left Bundle Branch Area Pacing (LBBAP)

- Verbalize why a 12 lead ECG is necessary during follow-up of a Left bundle branch pacing (LBBAP) lead
- Identify the characteristics of a right bundle branch block on ECG
- Identify non-selective (ns-LBBAP) vs selective (s-LBBAP) capture during threshold testing for LBBAP lead
- Identify Anodal stimulation for a LBBAP lead
- Identify LV septal capture characteristics

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12 Lead ECG

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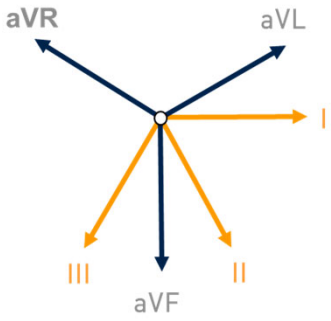
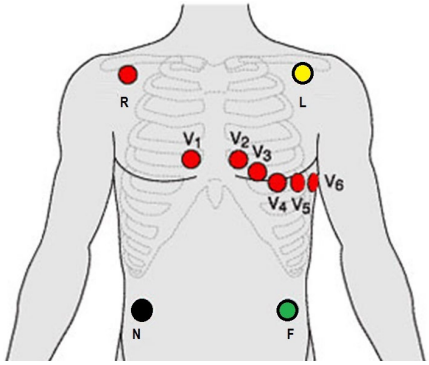
12 Lead ECG
Electrode Placement

- 12 lead electrocardiogram (ECG) is a representation of the heart's electrical activity recorded from electrodes placed on the body between 2 poles, a negative and positive pole
- 12 lead ECG is needed during follow-up for a LBBAP lead to visualize lead V1





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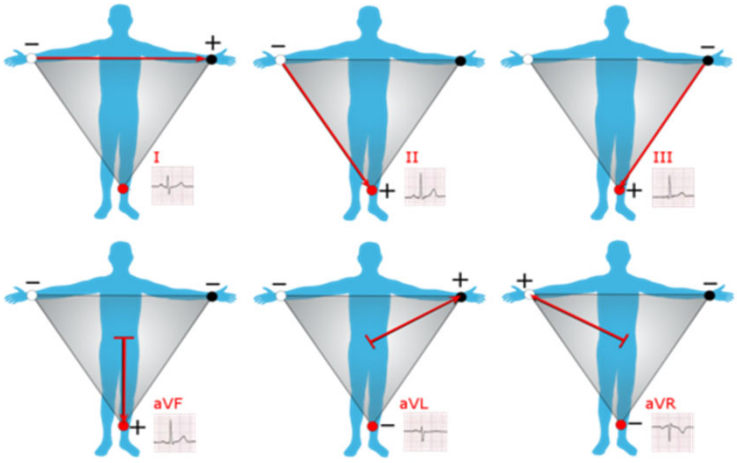
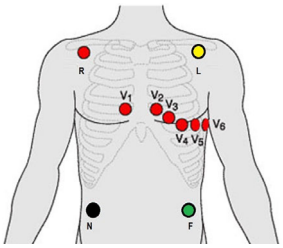
Basic 12 Lead ECG

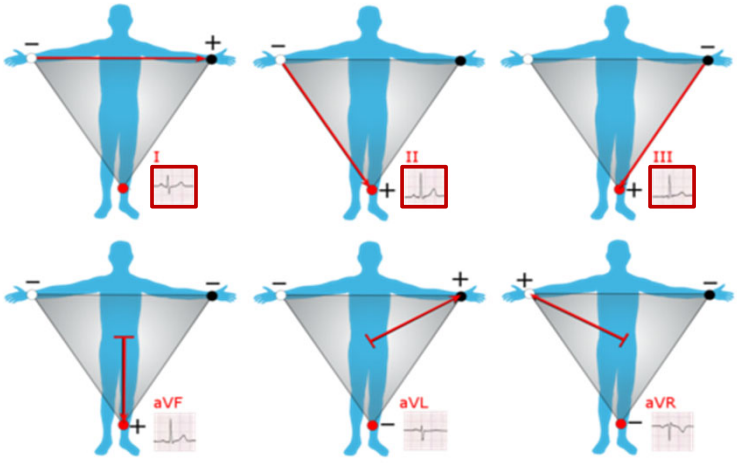


12 Lead ECG consists of

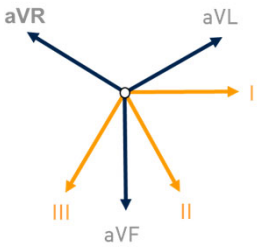
- 3 bipolar limb leads: I, II, III
- 3 unipolar limb leads: aVR, aVL, aVF
- 6 unipolar chest leads V1-V6 (also known as the precordial leads)



Basic 12 Lead ECG

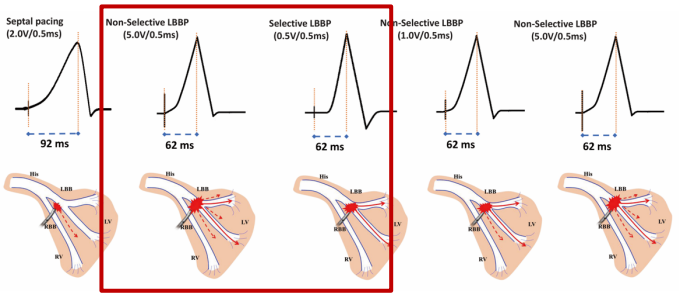


- The wave of depolarization moving towards a positive electrode results in a positive deflection of the ECG
- The wave of depolarization moving towards a negative electrode results in a negative deflection of the ECG



Why is a 12 Lead ECG necessary for LBBAP pacing lead?

- When performing threshold tests, a 12-lead ECG is important to recognize the various types of capture (selective versus non-selective conduction system capture, myocardial capture only or anodal capture)[1]
- Transition in QRS morphology is the gold standard to assess capture[2]
- Paced 12-lead ECGs are mandatory during in-person follow-up to assess LBBAP capture[2]



1. Bakelants E, Burri H. Troubleshooting Programming of Conduction System Pacing. Arrhythm Electrophysiol Rev. 2021 Jul;10(2):85-90. doi: 10.15420/aer.2021.16. PMID: 34401180; PMCID: PMC8335852.

2. Burri H, Jastrzebski M, Cano Ó, Čurila K, de Pooter J, Huang W, Israel C, Joza J, Romero J, Vernooy K, Vijayaraman P, Whinnett Z, Zanon F. EHRA clinical consensus statement on conduction system pacing implantation: endorsed by the Asia Pacific Heart Rhythm Society (APHRS), Canadian Heart Rhythm Society (CHRS), and Latin American Heart Rhythm Society (LAHRS). Europace. 2023 Apr 15;25(4):1208-1236. doi: 10.1093/europace/euad043. PMID: 37061848; PMCID: PMC10105878.

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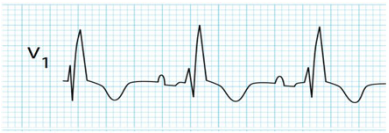
Why is a 12 Lead ECG necessary for LBBAP lead?

Why the need to visualize lead V1
- If capturing a portion of the left side conduction system, should be creating a right bundle branch block appearance on the ECG
- RSR prime in V1



With LBB pacing this is referred to as a terminal R wave
- The terminal R wave represents delayed activation of the right ventricle

Loss of a terminal R wave at follow-up
- If possible and available, compare current 12 lead ECG with post implant 12 lead ECG

Loss of terminal R-wave in V1 over follow-up was reported in 4% of patients in the MELOS registry. This highlights the importance of the 12-lead ECG at follow-up visits.[1]

1. Burri H, Jastrzebski M, Cano Ó, Čurila K, de Pooter J, Huang W, Israel C, Joza J, Romero J, Vernooy K, Vijayaraman P, Whinnett Z, Zanon F. EHRA clinical consensus statement on conduction system pacing implantation: endorsed by the Asia Pacific Heart Rhythm Society (APHRS), Canadian Heart Rhythm Society (CHRS), and Latin American Heart Rhythm Society (LAHRS). Europace. 2023 Apr 15;25(4):1208-1236. doi: 10.1093/europace/euad043. PMID: 37061848; PMCID: PMC10105878.

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Definitions

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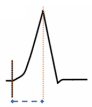
Conduction System Pacing

Definitions

Selective LBBAP (S-LBBAP) and non-selective LBBAP (NS-LBBAP) are two subgroups of LBBAP[1]

Non-selective LBBAP *No stim-QRS latency; no discrete local EGM separate from stimulus artifact*[1]	• LBB and adjacent myocardium are captured	
Selective LBBAP S-LBBAP: *Stim-QRS latency and discrete local EGM separate from stimulus artifact seen*[1]	• Only the LBB trunk or its proximal fascicles is captured • As pacing output is decreased, lose local myocardial capture	
LV Septal (LVS) Pacing[1]	• Left ventricular septal myocardium only is captured	
Anodal Stimulation (Bipolar pacing configuration)[1]	• Stimulation of ring electrode captures right side of septum • Simultaneous LBB capture at Tip Electrode	

1. Reference: Zhu K, Chang D, Li Q. Which Is More Likely to Achieve Cardiac Synchronization: Left Bundle Branch Pacing or Left Ventricular Septal Pacing? Front Cardiovasc Med. 2022 Mar 28;9:845312.

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Non-Selective vs Selective vs LVS Pacing Criteria LBBAP

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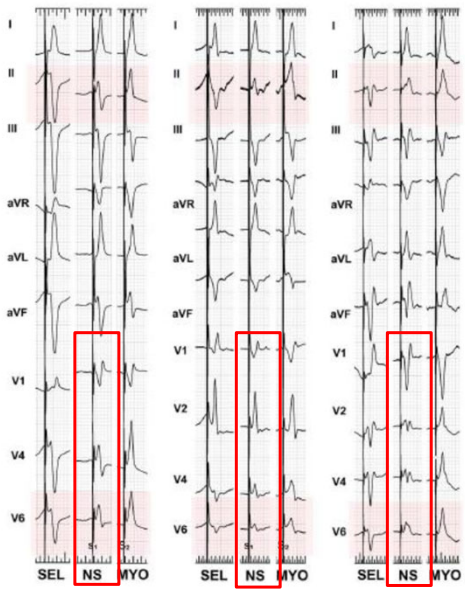
Selective vs Non-Selective LBBAP

Possible pacing responses with LBBAP[1]

Differences best visualized in lead V1

NS-LBBAP:

- Fusion between S-LBBAP and LVSP
- Clear R' in V1, narrow QRS
- QRS waveform positive but less high in V4-V6



Documented with programmed ventricular extrastimuli pacing

1. Dr. Jan De Pooter, BIOTRONIK training, BIOTRONIK Training video 2022

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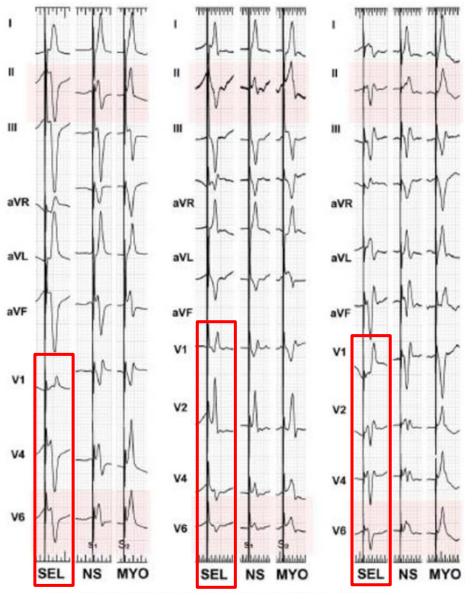
Selective vs Non-Selective LBBAP

Possible pacing responses with LBBAP[1]

Differences best visualized in lead V1

S-LBBP:

- Large R' in V1
- Latency interval (separation) between pacing spike and QRS onset (not always clear)



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1. Dr. Jan De Pooter, BIOTRONIK training, BIOTRONIK Training video 2022

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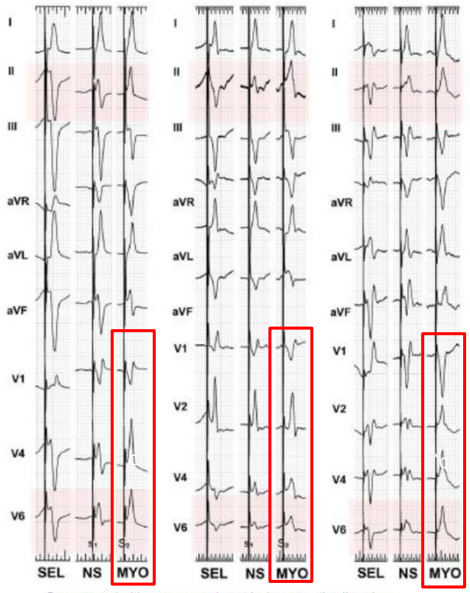
Selective vs Non-Selective LBBAP

Possible pacing responses with LBBAP[1]

Differences best visualized in lead V1

LVSP (myocardial capture):

- Broader and notched QRS morphology
- Most often R', but sometimes Loss of r' in V1



Documented with programmed ventricular extrastimuli pacing

1. Dr. Jan De Pooter, BIOTRONIK training, BIOTRONIK Training video 2022

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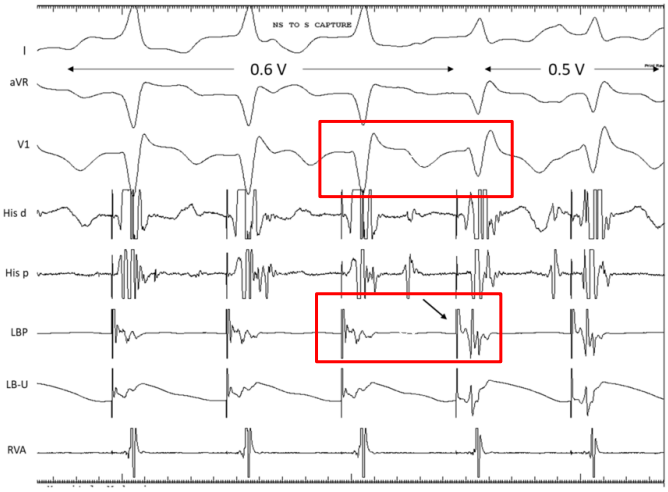
Left Bundle Branch Pacing

Non-selective-Selective LBBAP capture

Note the following changes during transition from ns-LBBAP to s-LBBAP

- Slight change in QRS morphology in V1
- Separation of pacing output from QRS with s-LBB capture



Reference: Ponnusamy, S.S., Muthu, G., Kumar, M. et al. Mid-term feasibility, safety and outcomes of left bundle branch pacing–single center experience. J Interv Card Electrophysiol 60, 337–346 (2021). https://doi.org/10.1007/s10840-020-00807-w

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Follow-up for a LBBAP lead

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Follow-Up Protocol

2023 HRS/APHRS/LAHRS guideline on cardiac physiologic pacing for the avoidance and mitigation of heart failure

In patients who have had a CSP device implanted, a 12-lead ECG, including long strips during threshold testing, can help to ensure and optimize maximal conduction system capture. The tracing should be evaluated to determine capture thresholds, LBBB correction when pertinent, and type of capture (selective vs nonselective conduction system capture). The paced QRS duration and morphology should be compared to prior readings and used as a comparison point for future follow-up[1]

1. Chung MK, Patton KK, Lau CP, et al. 2023 HRS/APHRS/LAHRS guideline on cardiac physiologic pacing for the avoidance and mitigation of heart failure. *Heart Rhythm*. 2023;20(9):e17-e91. doi:10.1016/j.hrthm.2023.03.1538

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Follow-Up Protocol

LBBAP follow-up may be less frequent as compared to His Bundle follow up and rely more on remote device management if capture thresholds are reliably measured by the device[1]

- Consider the following (clinician preference)
  - 1 week post operative
  - 3 and 6 months post operative
  - If lead remains stable at 6 months post op check, consider yearly check

1. Burri H, Jastrzebski M, Cano Ó, Čurila K, de Pooter J, Huang W, Israel C, Joza J, Romero J, Vernooy K, Vijayaraman P, Whinnett Z, Zanon F. EHRA clinical consensus statement on conduction system pacing implantation: endorsed by the Asia Pacific Heart Rhythm Society (APHRS), Canadian Heart Rhythm Society (CHRS), and Latin American Heart Rhythm Society (LAHRS). Europace. 2023 Apr 15;25(4):1208-1236. doi: 10.1093/europace/euad043. PMID: 37061848; PMCID: PMC10105878.

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Follow Up Testing on a Left Bundle Branch Pacing lead Best Practices

Perform a 12 lead ECG simultaneously with threshold test

- Why? need to visualize lead V1 to confirm LBBAP

Perform Sensing, Impedance, and Threshold testing on LBBAP lead

- Once threshold test is complete, go back and analyze the 12 lead ECG with each decrement
  - *Was there Anodal stim at high output?*
  - *Was there a transition from NS-LBB to S-LBB capture?*
  - *What was the threshold?*

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Left Bundle Branch Lead Testing

Best Practice-Steps when performing a threshold test

- Perform threshold test simultaneously with ECG
  - Set pulses to 3
  - Continue to decrement output until loss of capture (LOC)
- Review 12 lead ECG print out (decrement is every 3 pulses)
- Identify and document output at which transition(s) may occur
  - Transition from ns-LBB to s-LBB confirms LBB capture
- Identify and document output at which LOC occurs
  - Program output 2x safety margin

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Follow-up LBBAP Examples

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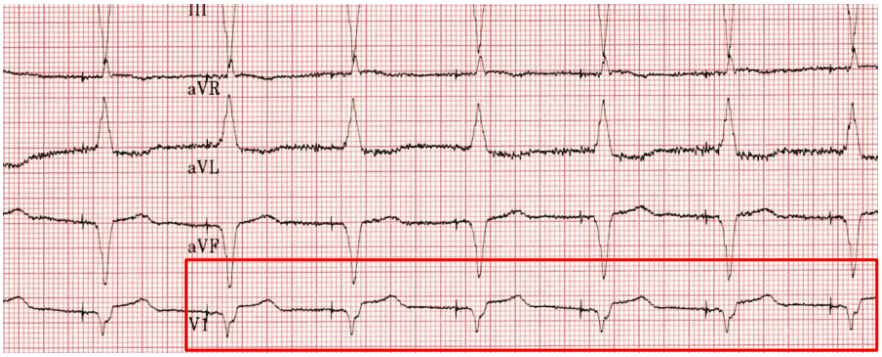
Left Septal Capture

Looking at a lead V1 in this example. What type of capture is occurring?

(Select the best answer)

- Non-Selective (ns) LBB capture
- Selective LBB capture
- Septal Capture
- None of the above



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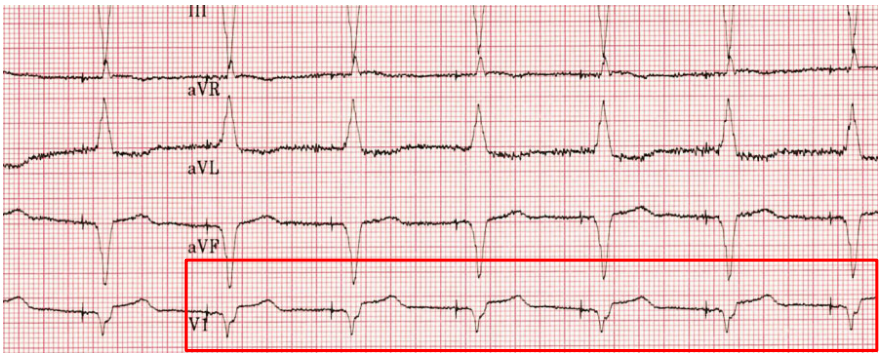
Left Septal Capture

Looking at a lead V1 in this example. What type of capture is occurring?

(Select the best answer)

- Non-Selective (ns) LBB capture
- Selective LBB capture
- **Septal Capture**
- None of the above



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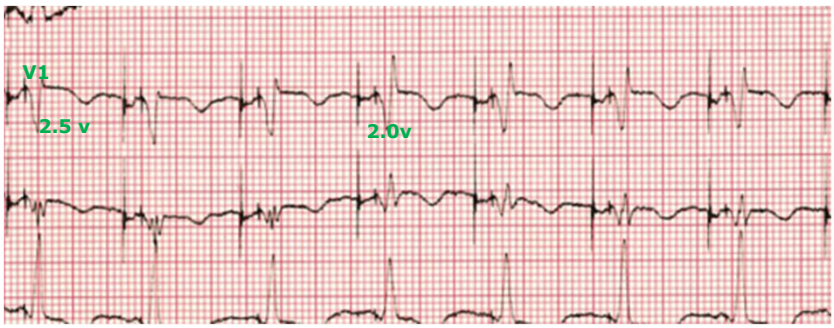
Anodal to ns-LBBAP

Looking at a lead V1 in this example. What type of capture is occurring?

(Select the best answer)

a. Non-Selective (ns) LBB capture
b. Selective LBB capture
c. Septal Capture
d. Anodal to ns-LBB capture



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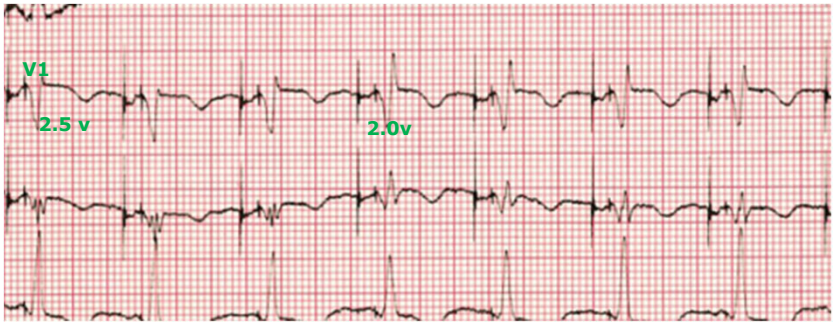
Anodal to ns-LBBAP

Looking at a lead V1 in this example. What type of capture is occurring?

(Select the best answer)

a. Non-Selective (ns) LBB capture
b. Selective LBB capture
c. Septal Capture
d. Anodal to ns-LBB capture



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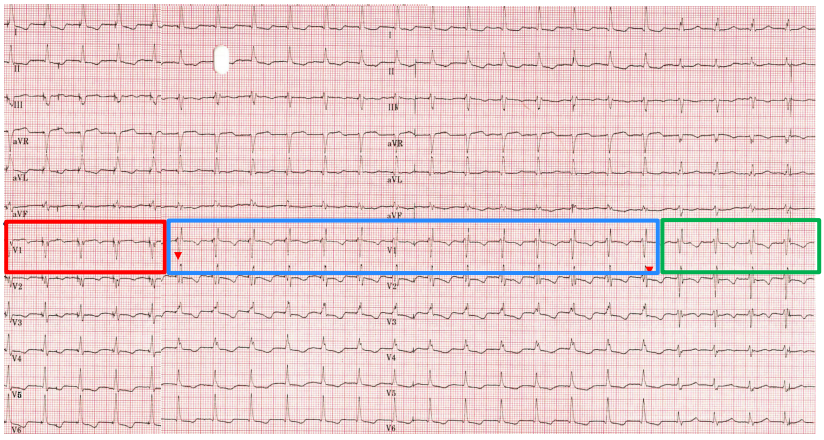
Case Study

Threshold Test

Looking at a lead V1 in this example. What type of capture is occurring?

(Select the best answer)

a. Non-Selective (ns) LBB capture
b. Selective LBB capture
c. Septal Capture
d. Anodal to ns-LBB capture to selective LBB capture



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Case Study

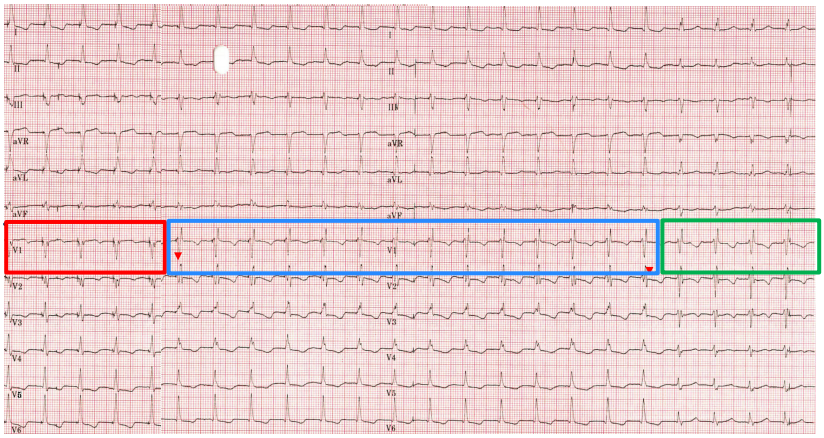
Threshold Test

Looking at a lead V1 in this example. What type of capture is occurring?

(Select the best answer)

a. Non-Selective (ns) LBB capture
b. Selective LBB capture
c. Septal Capture
d. Anodal to ns-LBB capture to selective LBB capture

Identify the following
- Anodal stimulation
- NS-LBBAP
- S-LBBAP



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Programming Resource

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Programming LBBAP Per Physician Preference
Not BIOTRONIK Specific

Table 1: Programming Recommendations for LBBAP

Parameter	Recommendation HBP	Recommendation LBBAP
Pacing mode	Single-chamber device: VVI Dual-chamber or CRT device: • HBP lead in a ventricular port: DDD(R), DDI or managed ventricular pacing mode • HBP lead in atrial port (chronic AF) with backup ventricular lead: DDD(R), DDI(R), or DVI(R) if available	Single-chamber device: VVI Dual-chamber or CRT device: • LBBAP lead in a ventricular port: DDD(R), DDI or managed ventricular pacing mode • LBBAP lead in atrial port (chronic AF) with backup ventricular or ICD lead: DDI(R), or DVI(R) if available
Pacing polarity	Unipolar (better visibility or the pacing spike to avoid confounding with intrinsic rhythm, lower capture thresholds) Bipolar (lower current drain due to higher impedance)	Bipolar (lower current drain due to higher impedance; anodal capture may narrow the QRS) Unipolar if anodal capture is not desirable
Sensing vector	Bipolar (unipolar can be tried if low sensing amplitude or P wave/HB potential oversensing)	Bipolar
Sensitivity	HBP lead connected to atrial channel: set to the maximum value (minimum sensitivity), as ventricular sensing is provided by the backup ventricular lead HBP lead connected to RV channel: adjust the level to ensure ventricular sensing, yet avoid oversensing of atrial or HB potentials.	Usually, not an issue as R waves are of high amplitude
Output voltage	2 x threshold voltage Fixed safety margin, e.g. 1V above the threshold, in non-dependent patients	2 x threshold voltage
Impulse duration	0.4 ms (1.0 ms if high capture threshold). 0.2-0.4 ms may be programmed according to chronaxle	0.4 ms (capture threshold is rarely an issue)
Automatic capture control algorithms	Deactivate, monitoring only (may be inaccurate or impossible to measure, especially if the HBP lead is connected to the atrial port), or activate only once the accuracy has been confirmed in the patient	Set to monitor or automatic once the accuracy has been confirmed in the patient
AV delay	HBP lead in ventricular port: Subtract HV interval (e.g. 40 ms) from desired AV interval	LBBAP lead in ventricular port: Subtract LBB-V interval (e.g. 20 ms) from desired AV interval

Bakelants E, Burri H. Troubleshooting Programming of Conduction System Pacing. *Arrhythm Electrophysiol Rev.* 2021;10(2):85-90. doi:10.15420/aer.2021.16

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Programming LBBAP Per Physician Preference (continued)
Not BIOTRONIK Specific

AV delay	HBP lead in ventricular port: Subtract HV interval (e.g. 40 ms) from desired AV interval HBP lead in atrial port with backup ventricular pacing: AV delay >His pace-RVSS interval (e.g. 150 ms) HBP lead in atrial port with HOT-CRT: optimize AV interval based on QRS narrowing, or program empirically to 60% of the His pace – RV sense interval (usually 40-60 ms)[8]	LBBAP lead in ventricular port: Subtract LBB-V interval (e.g. 20 ms) from desired AV interval LBBAP lead in atrial port with backup ventricular pacing: AV delay >LBBAP-RVS interval (e.g. 150 ms) LBBAP lead in atrial port with LOT-CRT: optimize AV interval based on QRS narrowing
VV delay (CSP lead connected to LV port)	With backup RV pacing: program maximum LV channel pre-excitation (e.g. 80 ms) In case fusion with RV pacing is desirable (e.g. in case of uncorrected RBBB): program LV channel pre-excitation 30-60 ms, optimized by surface ECG	With backup RV pacing (e.g. with ICD lead): program maximum LV channel pre-excitation (e.g. 80 ms)
Ventricular safety pacing	Deactivate if the HBP lead is connected to the atrial port with an RV back-up lead, after having verified absence of crosstalk	Deactivate if the LBBAP lead is connected to the atrial port with an RV back-up lead (e.g. with an ICD or in case of LOT-CRT), after having verified absence of crosstalk
Automatic sensing control algorithms	Deactivate (IP wave oversensing and HB sensing (may lead to asystole!)	Can be left on
Sensing if CSP lead connected to LV port	Deactivate (BIOTRONIK, Boston-Scientific)	Deactivate (BIOTRONIK, Boston-Scientific)
AV and VV optimization algorithms	Deactivate	Deactivate
Ventricular triggered pacing (ventricular sense response, etc.)	Deactivate	Deactivate

AV = atrioventricular; CSP = conduction system pacing; HB = His bundle pacing; HV = His-ventricle; HOT-CRT = His-optimized CRT; LBB = left bundle branch; LBBAP = left bundle branch area pacing; LOT-CRT = left bundle branch pacing optimized CRT; LV = left ventricular; RBBB = right bundle branch block; RV = right ventricular; VSP = ventricular safety pacing; VV = interventricular.

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Quiz Questions

1. Which of the following ECG characteristics best describes ns-LBBP?
    a. Fusion between S-LBBP and LVSP, clear R‘ in V1 and narrow QRS
    b. Clear R’ in V6
    c. Latency interval between pacing spike and QRS onset (not always clear)
    d. None of the above

2. Which of the following ECG characteristics best describes s-LBBP?
    a. Fusion between S-LBBP and LVSP
    b. Large R’ in V1, narrow QRS and Latency interval (separation) between pacing spike and QRS onset (not always clear)
    c. Wide QRS with notching
    d. None of the above

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Quiz Questions

3. What is the reason for running a 12 lead ECG during threshold testing on a LBBP lead?
    a. Visualize possible transitions in limb lead I
    b. Visualize possible transitions in limb lead II
    c. Visualize possible transitions in lead V1
    d. None of the above
4. Which of the following ECG characteristics best describes LVS capture?
    a. Fusion between S-LBBP and LVSP
    b. Most often R’, but sometimes Loss of r’ in V1, broader and notched QRS morphology
    c. Large R’ in V1, narrow QRS and Latency interval (separation) between pacing spike and QRS onset (not always clear)
    d. None of the above

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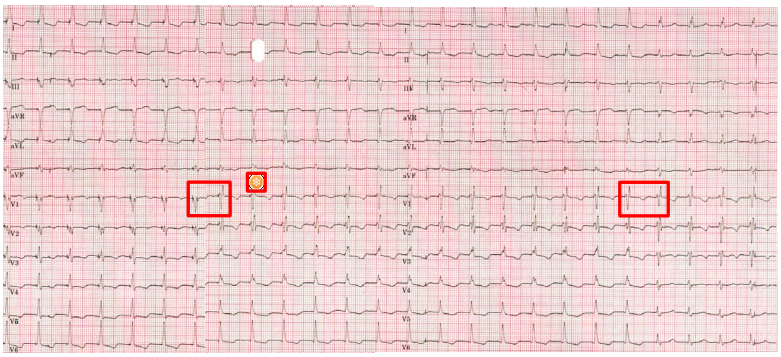
Quiz Questions

5. Which of the following best describes the transitions during threshold testing on the following ECG?
   a. Transition from LVS to ns-LBB pacing to s-VBBP
   b. Transition from Anodal stim to ns-LBBP to s-LBBP
   c. Transition from Anodal stim to s-LBB to ns_LBBP
   d. None of the above



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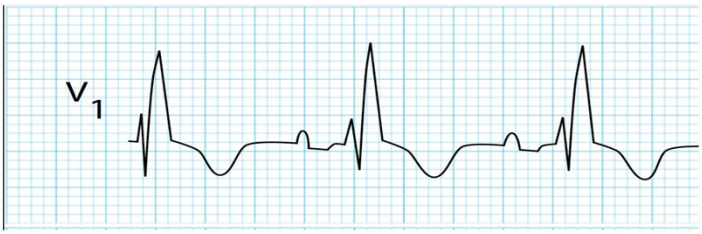
Quiz Questions

6. The following ECG can best be described as which of the following?
   a. Left bundle branch block
   b. Right bundle branch bloc
   c. Neither a right or left bundle branch block



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Quiz Questions

7. When performing a threshold test on a left bundle pacing lead, which of the following are best practices?
   a. Perform a 12 lead ECG simultaneously with threshold test
   b. Review 12 lead ECG print out and review for possible transitions
   c. Identify LOC and program output per standard 2 times safety margin
   d. All of the above

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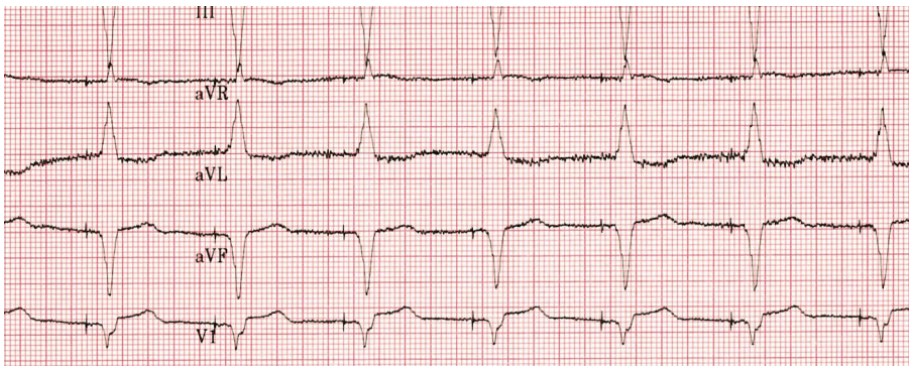
Quiz Questions

8. Which of the following best describes the type of LBBP on the ECG?
   a. ns-LBB pacing
   b. s-LBB pacing
   c. LVS pacing
   d. None of the above



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