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**Comparing His Bundle Branch and Left Bundle Branch Area Pacing
in Cardiac Resynchronization Therapy: Safety, Feasibility, and
Predictors of Response**



Dissertation submitted in partial fulfilment of the requirements for MSc in Medical Device
Technology and Business.

Joel Joseph Joseph
August 2025

DECLARATION

I hereby declare that the dissertation titled “**Comparing His Bundle Branch and Left Bundle Branch Area Pacing in Cardiac Resynchronization Therapy: Safety, Feasibility, and Predictors of Response**” is submitted for the partial fulfilment of MSc in medical device technology and business and is purely my original work. I also confirm that I have not plagiarized anybody’s work either partially or entirely.

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A handwritten signature in black ink, appearing to be 'JP', written over a horizontal line.

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ABBREVIATIONS

Abbreviation	Meaning
AV	Atrioventricular (node or conduction)
BiV	Biventricular
CCU	Cardiac Care Unit
CRT	Cardiac Resynchronization Therapy
CRT-D	Cardiac Resynchronization Therapy-Defibrillator
CRT-P	Cardiac Resynchronization Therapy-Pacemaker
CS	Coronary Sinus
CSP	Conduction System Pacing
ECG	Electrocardiogram
EP	Electrophysiologist/Electrophysiology
HBP	His Bundle Pacing
ICD	Implantable Cardioverter Defibrillator
LBBB	Left Bundle Branch Block
LBBAP	Left Bundle Branch Area Pacing
LV	Left Ventricle
LVEF	Left Ventricular Ejection Fraction

Abbreviation	Meaning
NYHA	New York Heart Association
RA	Right Atrium
RV	Right Ventricle
SA	Sinoatrial (node or conduction)

ABSTRACT

This study explored the use of two advanced pacing techniques, His Bundle Pacing (HBP) and Left Bundle Branch Area Pacing (LBBAP), for cardiac resynchronization therapy (CRT). The goal was to compare their pacing performance, safety, feasibility, and predictors of response using thematic analysis of semi structured interview conducted with electrophysiologists, cardiologists, nurses, and cardiac rhythm management technicians who have hands-on experience with these pacing methods.

The findings revealed that both HBP and LBBAP improve the heart's electrical activation more naturally than traditional biventricular pacing. However, LBBAP showed several advantages, including more consistent and narrower QRS complexes in ECG, lower pacing thresholds, and better sensing effectiveness. These features contribute to longer device life and fewer complications in future. LBBAP was also found to be easier to implant, with faster procedure times and more reproducible results after initial training. Its use was preferred especially in elderly or frail patients and those with complex heart anatomy. In contrast, HBP was often technically demanding and less predictable, requiring precise placement in the HIS bundle area and sometimes leading to re-interventions due to loss of heart rhythm capture.

The study identified key factors that guide the decision to use one method over the other, such as the heart's anatomy, the patient's overall health, and the history of prior leads or devices. Narrowing of the QRS complex, a marker of synchronized ventricular contraction, stable pacing thresholds, and strong sensed signals were important predictors of successful therapy. Clinicians noted that LBBAP generally met these criteria across a wider range of patients.

Recommendations were made to adopt LBBAP as the preferred approach in routine clinical practice while reserving HBP for select cases. Further research was encouraged to investigate long-term outcomes and complicated patient groups.

Overall, this work provides valuable insights into the practical use of both conduction system pacing therapies in heart failure and supports the growing adoption of LBBAP to improve patient care.

Keywords: Cardiac resynchronization therapy; His Bundle Pacing; Left Bundle Branch Area Pacing; Heart failure; Pacing performance; Sensing amplitude; QRS narrowing; Patient selection; Ejection Fraction; Clinical outcomes.

CHAPTER 1

1.1 Introduction

Heart failure continues to be a major cause of morbidity and mortality globally, with its prevalence increasing despite advancements in pharmacological and device therapies (Ponikowski *et al.*, 2016). Cardiac resynchronization therapy (CRT) is indicated for patients with heart failure who exhibit electrical dyssynchrony, most commonly defined by a left ventricular ejection fraction of 35% or less and a QRS duration greater than 150 millisecond (Daubert and Linde, 2024a). Cardiac resynchronization therapy (CRT) devices are of two types: CRT-P (Cardiac Resynchronization Therapy-Pacemaker) and CRT-D (Cardiac Resynchronization Therapy-Defibrillator). Both HBP and LBBAP can be incorporated into CRT-P and CRT-D systems by connecting specialized pacing leads to the device's left ventricular (LV) port, enabling this conduction system pacing techniques to deliver physiologic resynchronization therapy in place of, or as an alternative to, traditional biventricular pacing leads. Cardiac resynchronization therapy has been administered using biventricular pacing (BiV), a technique that synchronizes left and right ventricular contractions by pacing both chambers concurrently. Nevertheless, a significant percentage of patients; reported to be between 30% and 40%; do not respond adequately to standard BiV pacing. This lack of response is frequently attributed to factors such as less-than-ideal lead positioning and the fundamentally non-physiological nature of ventricular activation associated with this method. (Wells *et al.*, 2011; Ali *et al.*, 2023a)



Fig 1: CRT Device with three ventricular leads (BiV Pacing)(Sarvestani, 2025)

In recent years, conduction system pacing (CSP) methods; most notably His Bundle Pacing (HBP) and Left Bundle Branch Area Pacing (LBBAP); have been developed as advanced alternative to BiV pacing intended to replicate the heart's native electrical conduction more accurately. His Bundle Pacing entails the direct activation of the His bundle, which serves as the primary conduit for ventricular excitation, thereby maintaining natural depolarization patterns and atrioventricular synchrony. (Lustgarten *et al.*, 2015a) Left Bundle Branch Area Pacing (LBBAP), as a newer technique, involves delivering pacing stimuli to the region of the left bundle branch within the interventricular septum. This approach facilitates prompt and coordinated activation of the left ventricle, including in cases where a proximal conduction block is present. (Huang *et al.*, 2019a; Vijayaraman *et al.*, 2021)

Growing evidence suggests that LBBAP may offer several advantages over HBP and traditional BiV pacing, including lower and more stable pacing thresholds, higher R-wave sensing amplitudes, and greater QRS narrowing features that are associated with improved device longevity, sensing reliability, and electrical synchrony(Vijayaraman *et al.*, 2023a). In a comprehensive meta-analysis, (Zhuo *et al.*, 2022) demonstrated that LBBAP consistently outperformed HBP in terms of pacing thresholds and sensing, while also achieving superior reductions in QRS duration during follow-up. These findings are echoed by(Ali *et al.*, 2023b), who reported that LBBAP provided more effective ventricular resynchronization and hemodynamic improvement compared to both HBP and BiV pacing in acute crossover studies. Despite these promising results, the adoption of CSP in routine clinical practice is not without challenges. HBP, while physiologically appealing, is technically demanding, often associated with higher and unstable thresholds, and carries a greater risk of lead dislodgement (Vijayaraman *et al.*, 2021). LBBAP, is more technically feasible and reproducible as it has higher success rates, shorter learning curve, and more consistent lead placement. But it requires careful procedural technique to avoid septal perforation and ensure true left bundle capture (Vijayaraman *et al.*, 2023a). Furthermore, real-world data on procedural safety, long-term outcomes, and predictors of response remain limited, with most studies to date being single-centre or observational in nature (Pothineni *et al.*, 2022).

Understanding patient-specific predictors of CRT response is a critical area of ongoing research. Factors such as QRS duration and morphology, left ventricular ejection fraction, duration of heart failure, and mechanical dyssynchrony have all been implicated in determining the likelihood of a favourable response (Parikh *et al.*, 2022). However, the impact of pacing modality; whether HBP or LBBAP; on these predictors, as well as on long-term clinical outcomes such as heart failure hospitalization and quality of life, is not yet fully understood.

Given these gaps, this research aims to provide a comprehensive, real-world comparison of HBP and LBBAP in the context of CRT, focusing on their performance, safety, feasibility, and predictors of response. By gathering qualitative insights from electrophysiologists, cardiologists, cardiac care nurses, and rhythm management technicians, this study seeks to bridge the divide between controlled clinical trials and everyday clinical practice.

1.2 Research Title:

Comparing His Bundle Branch and Left Bundle Branch Area Pacing in Cardiac Resynchronization Therapy: Safety, Feasibility, and Predictors of Response.

1.3 Significance and Justification

Despite advancements in cardiac resynchronization therapy (CRT), a notable proportion of patients continue to exhibit suboptimal responses to conventional biventricular pacing, largely due to its non-physiological ventricular activation (Ali *et al.*, 2023b). Conduction system pacing modalities, specifically His Bundle Pacing (HBP) and Left Bundle Branch Area Pacing (LBBAP), have emerged as promising alternatives that more closely replicate the heart's intrinsic conduction pathways and may overcome the limitations of traditional approaches (Zhuo *et al.*, 2022) (Lustgarten *et al.*, 2015b).

Given the limited qualitative data on clinician experiences and the real-world implementation of these strategies, this study is both timely and necessary. By exploring the perspectives of healthcare professionals directly involved in CRT delivery, this research will provide valuable insights into the comparative safety, feasibility, and determinants of response for HBP and LBBAP. These findings will help inform clinical decision-making, guide future device development, and ultimately contribute to optimizing patient outcomes in CRT.

1.4 Aim and Objective

1.4.1 Aim of Research

This research aims to compare the use of His Bundle Branch and Left Bundle Branch area pacing in Cardiac Resynchronization Therapy while analysing its safety, feasibility and predictors of response.

1.4.1 Objectives

- Investigate clinician perspectives on pacing performance in CRT systems by gathering insights and experiences related to pacing thresholds, sensing effectiveness, and ventricular activation patterns with HBP and LBBAP.
- Determine Safety and Feasibility: Assess the procedural success, complications, and long-term safety of CRT.
- Identify Predictors of Response: Analyse patient-specific factors that predict a favourable response to each pacing strategy.

1.4.2 Research Questions

1. How do clinicians describe their experiences with pacing performance; specifically pacing thresholds, sensing effectiveness, and ventricular activation patterns; when using His Bundle Pacing (HBP) versus Left Bundle Branch Area Pacing (LBBAP) in CRT?
2. What are the perceived safety and feasibility considerations of HBP and LBBAP in CRT, including procedural success, complication profiles, and long-term device performance, as reported by clinical practitioners?
3. Which patient-specific factors do healthcare professionals identify as key predictors of a favourable response to HBP or LBBAP in CRT?
4. How do clinicians evaluate the impact of HBP and LBBAP on long-term patient outcomes, such as symptom improvement, hospital readmissions, and quality of life?
5. What practical challenges and decision-making processes do clinicians encounter when selecting between HBP and LBBAP for individual CRT patients.

1.5 Structure of Dissertation

The subsequent chapters of this dissertation are structured to systematically address the research questions outlined above. **Chapter 2** offers a detailed review of existing literature, tracing the development of cardiac resynchronization therapy and conduction system pacing, and highlighting key studies that inform current clinical practice. **Chapter 3** describes the research methodology, including the study design, participant selection, data collection techniques, and the analytical approaches employed. In **Chapter 4**, the results of the study are presented, encompassing qualitative findings related to the performance, safety, and feasibility of His Bundle Pacing and Left Bundle Branch Area Pacing in CRT. This chapter also discusses these findings in the context of previous research, examining their implications for clinical practice, the limitations of the study, and directions for future investigation. Finally, **Chapter**

5 summarizes the principal conclusions and offers recommendations to enhance the implementation and outcomes of conduction system pacing in cardiac resynchronization therapy.

CHAPTER 2

2.1 Introduction

This chapter presents a thorough examination of the current literature surrounding Heart's Conduction System, Arrhythmias, impact of CRT, His bundle pacing (HBP) and left bundle branch area pacing (LBBAP), with a particular focus on their roles in cardiac resynchronization therapy (CRT). The review systematically explores the procedural aspects of these advanced pacing modalities, including implantation success rates and the incidence of complications, as reported in recent multicentre studies and clinical trials. Special attention is given to the identification of clinical and electrophysiological factors that predict favourable outcomes, such as improvements in left ventricular function and symptomatic relief in heart failure patients. Additionally, the chapter discusses the comparative advantages and limitations of HBP and LBBAP, drawing on evidence from both randomized and observational research. By analysing these findings, the chapter aims to provide a nuanced understanding of the evolving landscape of conduction system pacing, highlight areas where consensus has been achieved, and identify unresolved questions that continue to drive research in this field. This comprehensive review serves as a foundation for the subsequent analysis and interpretation of the present study's findings.

2.2 Conduction System and Arrhythmias

The heart's ability to conduct in a coordinated rhythm relies on the electrical conduction system. This system, as described by (Kennedy *et al.*, 2016), starts with the sinoatrial (SA) node, a small cluster of specialised cells located in the right atrium. The SA node is often called the heart's natural pacemaker because it generates electrical impulses that set the pace for the entire heart. These impulses spread across the atria, causing them to contract and push blood into the ventricles.

After the atrial contraction, the electrical signal reaches the atrioventricular (AV) node, located at the junction between the atria and ventricles. (Vijayaraman *et al.*, 2023b) states that the AV node plays a significant role in heart's conduction system. It briefly delays the electrical impulse, giving the ventricles enough time to fill with blood before they contract. This delay is essential for efficient heart function and is visible as the PR interval on an electrocardiogram. The PR interval marks the period between the initiation of atrial depolarisation and the onset of ventricular depolarisation, primarily reflecting the electrical conduction through the atrioventricular node.

From the AV node, the electrical signal travels down the bundle of His. The bundle of His is a specialised group of heart muscle fibres that receives electrical signals from the atrioventricular node and rapidly conducts them through the interventricular septum, branching into the left and right bundle branches. These branches further divide into Purkinje fibres, which spread throughout the ventricular muscle. This network ensures that both ventricles contract almost simultaneously, effectively pumping blood to the lungs and the rest of the body (Cleveland, 2025; Kennedy *et al.*, n.d.)

The cells in the conduction system are different from ordinary heart muscle cells. (Sayers *et al.*, 2025) note that these specialised cells are connected by gap junctions, allowing electrical impulses to travel rapidly and uniformly. This network ensures the heart muscle contracts as a single unit, but it also means that any disruption in the system can adversely affect the whole heart.

Disruptions in the conduction system can lead to arrhythmias, which are abnormal heart rhythms. These can be harmless, but some are serious and even life-threatening. (Li *et al.*, 2024) points out that arrhythmias are generally classified by where they start and how they disrupt the normal rhythm. Bradyarrhythmias, for example, occur when the heart beats too slowly, often because the SA node isn't generating impulses quickly enough or because the AV node is blocking signals.

Tachyarrhythmias, on the other hand, are fast heart rhythms that can be caused by other electrical pathways or circuits within the heart. Atrial fibrillation is a common example, where chaotic electrical activity in the atria overwhelms the SA node and causes an irregular, rapid heartbeat. This can lead to poor blood flow, an increased risk of stroke, and other complications (Li *et al.*, 2024). Ventricular arrhythmias, such as ventricular tachycardia or ventricular fibrillation, are even more hazardous because they can stop the heart from pumping blood altogether, leading to sudden cardiac arrest (Sayers *et al.*, 2025).

(Mayo Clinic, 2025) states that the causes of arrhythmias are varied. They can result from congenital problems, heart disease, damage from a heart attack, or even certain medications. (Sayers *et al.*, 2025) and (Li *et al.*, 2024) both emphasise how changes at the molecular level, such as mutations in ion channels or damage to the gap junctions, can disrupt the natural flow of electricity through the heart. In some cases, inflammation or scarring from previous heart injuries can create areas that block or misdirect electrical impulses, leading to arrhythmias.

Recent advances in technology have significantly improved our understanding of the conduction system and arrhythmias. High-resolution imaging and mapping tools now allow doctors to see the exact pathways of electrical signals within the heart. This helps them

diagnose arrhythmias more accurately and target treatments more effectively (Vijayaraman *et al.*, 2023a; Mirmaksudov *et al.*, 2024). Newer pacing techniques, such as His bundle pacing and left bundle branch area pacing, aim to restore more natural electrical activation in patients who need pacemakers. According to (Mirmaksudov *et al.*, 2024), these approaches can help preserve heart function and reduce the risk of pacing-induced arrhythmias compared to traditional right ventricular pacing.

Despite these advances, managing arrhythmias remains a challenge.(Sayers *et al.*, 2025) and (Kennedy *et al.*, n.d.) point out that while pacemakers and defibrillators have saved countless lives, there is still a need for better medications and new therapies that target the underlying causes of conduction system disease. Researchers are exploring genetic and regenerative approaches that may one day help repair or replace damaged conduction tissue.

The heart's conduction system is essential for maintaining a healthy, coordinated heartbeat. When this system is disrupted, arrhythmias can arise, posing risks that range from mild symptoms to sudden death (Cleveland, 2025). Ongoing research and technological innovation continue to improve the ability to diagnose, treat, and even prevent these potentially serious conditions, offering hope for better outcomes in the future.

2.3 RV Pacing-Induced Dyssynchrony and Its Implications

Right ventricular (RV) pacing, particularly at the apex of the right ventricle, has long been a standard intervention for managing bradyarrhythmias and atrioventricular conduction disorders. However, a growing body of research highlights that RV pacing can disrupt the heart's normal activation sequence, leading to significant electrical and mechanical dyssynchrony with adverse clinical consequences.

(Mizner *et al.*, 2022) explain that RV pacing bypasses the heart's intrinsic conduction system, resulting in slow, cell-to-cell electrical propagation instead of the rapid transmission provided by the His-Purkinje network. This altered pathway leads to asynchronous contraction between the right and left ventricles, as well as within the left ventricle itself, a phenomenon termed interventricular and intraventricular dyssynchrony. Such dyssynchrony is a direct result of the initial depolarisation occurring at the pacing site, followed by delayed activation of remote left ventricular segments, which can be detected using advanced echocardiographic techniques like tissue Doppler imaging and speckle-tracking strain analysis.

(Tops *et al.*, 2009) further elaborate that RV apical pacing delays left ventricular (LV) activation, disrupting the normal timing of ventricular contraction. This mechanical discoordination impairs LV systolic function, leading to a reduction in ejection fraction and the

development or worsening of heart failure symptoms. Their work demonstrates that the abnormal activation pattern caused by RV pacing is associated with decreased cardiac output, altered LV filling, and changes in regional myocardial strain, all contributing to mechanical dyssynchrony and functional decline.

(Naqvi and Chao, 2023) emphasise that RV pacing-induced dyssynchrony also promotes mitral regurgitation by impairing the coordinated contraction of the papillary muscles and mitral valve apparatus. This leads to increased pre-ejection delay and reduced LV contractile performance, further accelerating the progression of heart failure. They also note that the adverse effects of RV pacing are more pronounced in patients with pre-existing LV dysfunction and are directly related to the percentage of pacing burden.

(Kim and Park, 2024) discuss pacing-induced cardiomyopathy as a chronic complication of RV pacing. This condition is characterised by adverse LV remodelling and reduced ejection fraction, which may develop over months or years of continuous pacing. Importantly, they point out that changes in LV function can sometimes be detected within hours of initiating RV pacing, aligning with clinical studies that show a notable increase in heart failure incidence during the initial weeks to months of high-burden pacing.

(Merchant *et al.*, 2017) provide clinical evidence that a high burden of RV pacing is linked to increased rates of heart failure hospitalization and atrial fibrillation. His findings suggest that even short-term RV pacing can acutely impair LV function, with some patients experiencing a rapid decline in ejection fraction within hours to weeks after pacing initiation. Notably, this acute impairment may persist even after normal conduction is restored, indicating lasting myocardial dysfunction in susceptible individuals.

(Osório *et al.*, 2017) highlight that the selection of the pacing site within the right ventricle can influence the degree of dyssynchrony. Their findings suggest that septal pacing may cause less interventricular dyssynchrony compared to apical pacing, although the clinical significance of this difference remains under investigation. This underscores the importance of individualised pacing strategies to minimize adverse effects and optimise outcomes.

RV pacing-induced dyssynchrony is a significant clinical challenge due to its association with impaired LV function, mitral valve dysfunction, heart failure progression, and increased morbidity. Advances in understanding these mechanisms have driven the development of more physiological pacing techniques and alternative pacing sites, aiming to mitigate these harmful effects and improve long-term outcomes for patients requiring ventricular pacing.

2.4 Clinical Evidence and Impact of Cardiac Resynchronization Therapy (CRT)

Cardiac resynchronization therapy (CRT) has become a transformative intervention for patients with heart failure and evidence of ventricular dyssynchrony (Daubert and Linde, 2024b). Over the past two decades, robust clinical trials and meta-analyses have established its efficacy in improving symptoms, reducing hospitalisations, and prolonging survival in appropriately selected patients.

The concept of CRT was pioneered in the early 1990s, with the aim of correcting electrical dyssynchrony in patients with heart failure and conduction disease. (Daubert and Linde, 2024c) highlight that the first proof of concept was established by the MUSTIC trial in 2001, which demonstrated that multisite pacing could significantly improve exercise capacity and quality of life in patients with advanced heart failure. This was soon followed by other pivotal randomised controlled trials (RCTs), including MIRACLE, COMPANION, CARE-HF, REVERSE, MADIT-CRT, and RAFT, each contributing to the evidence base supporting CRT's benefits across a spectrum of heart failure severity.

(Schiavone *et al.*, 2023a) emphasise that CRT via biventricular pacing is now a well-established therapy for patients with heart failure with reduced ejection fraction and left bundle branch block (LBBB), especially when symptoms persist despite optimal medical therapy. Across major RCTs, CRT has consistently reduced the risk of heart failure hospitalisations and all-cause mortality. For example, the COMPANION and CARE-HF trials showed a 30–40% reduction in the composite endpoint of death or heart failure hospitalisation in patients with New York Heart Association (NYHA) class III–IV symptoms and reduced ejection fraction (Daubert and Linde, 2024b).

While the majority of CRT evidence comes from patients with moderate to severe heart failure, recent analyses have expanded its indications. A patient-level meta-analysis by (Shivakumar *et al.*, 2024) found that CRT provides significant benefits even in those with the most severe symptoms (NYHA class IV), as well as in those with milder symptoms (class II), particularly when the QRS duration is prolonged. The REVERSE and MADIT-CRT trials demonstrated that CRT reduces heart failure events and improves LV remodelling even in patients with mild symptoms, though mortality reduction was more pronounced in those with more advanced disease (Lubitz *et al.*, 2010).

Despite strong evidence, CRT is not universally effective. (Schiavone *et al.*, 2023b) note that up to one-third of patients may not respond to traditional biventricular pacing, often due to anatomical challenges or suboptimal lead placement. This has driven the development of alternative pacing strategies, such as his bundle branch pacing and left bundle branch area

pacing, which may offer comparable efficacy and procedural advantages in selected patients. However, these approaches are still being evaluated in comparative studies.

Despite compelling evidence, (Daubert and Linde, 2024c) and (Schiavone *et al.*, 2023a) observe that CRT remains underutilised, with disparities in access based on geography, sex, and healthcare infrastructure. Further education is needed to ensure broader adoption of this life-saving therapy. Recent advances, including adaptive CRT algorithms and leadless pacing technologies, are being explored to further enhance outcomes and minimize complications.

2.5 CRT Device System

CRT systems are composed of two main components: the pulse generator (or device) and insulated wires known as leads. As explained by (Boston Scientific, 2025), the pulse generator is a small, battery-powered computer implanted under the skin, typically near the collarbone. This generator delivers tiny electrical impulses to the heart via the leads, which are threaded through veins and positioned within the heart's chambers. The leads are crucial for both sensing the heart's intrinsic electrical activity and delivering pacing stimuli to synchronize ventricular contractions.

There are two primary types of CRT devices: the CRT pacemaker (CRT-P) and the CRT defibrillator (CRT-D). The CRT-P, sometimes called a biventricular pacemaker, is designed to treat slow heart rhythms and resynchronize the ventricles. The CRT-D, in addition to providing resynchronization, incorporates an implantable cardioverter-defibrillator (ICD) capable of delivering life-saving shocks in the event of dangerous arrhythmias such as ventricular tachycardia or fibrillation. As highlighted by (Medtronic, 2024), the choice between CRT-P and CRT-D depends on the patient's risk profile for sudden cardiac death and the underlying rhythm disorder.(Boston Scientific, 2025)

During the implantation of a cardiac resynchronization therapy device, whether it is a CRT-D (with defibrillator) or CRT-P (without defibrillator), specialised leads are carefully positioned within the heart to achieve effective resynchronization. Typically, three leads are used: one for the right atrium (RA), one for the right ventricle (RV), and one for the left ventricle (LV), the latter usually placed in a branch of the coronary sinus.(Boston Scientific, 2025)

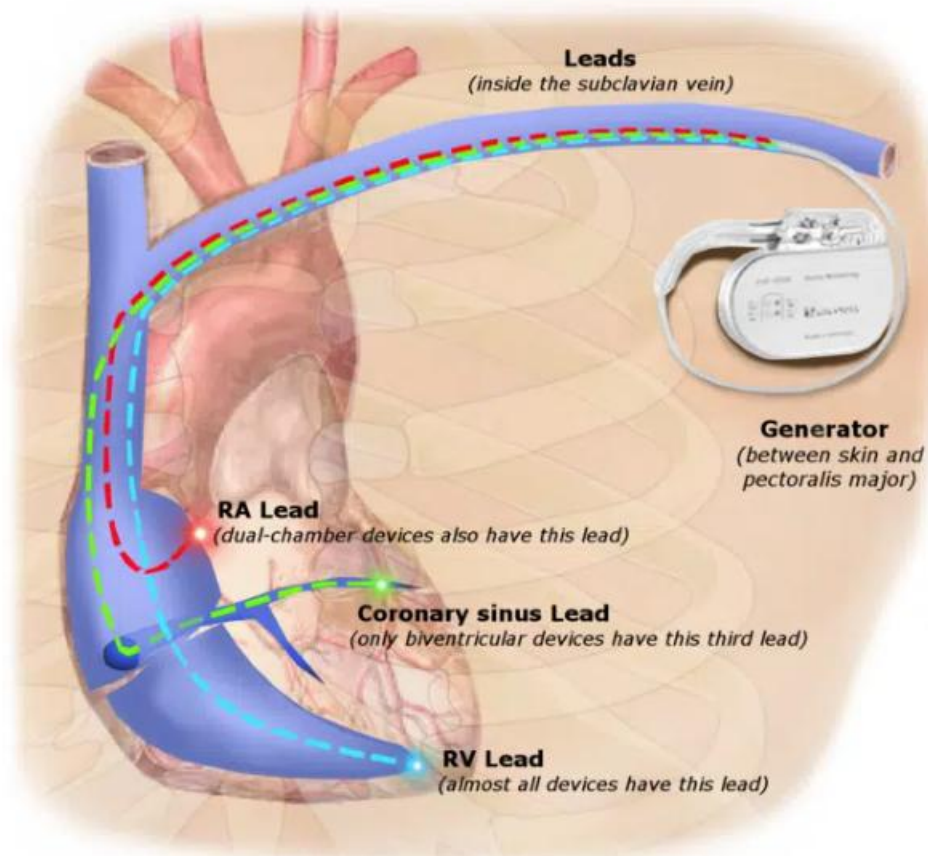


Fig 2: RA Lead, RV Lead and LV Lead (via Coronary Sinus) sites. (teachmeanatomy, 2025)

For CRT-D implantation, the procedure often begins with the placement of multiple hydrophilic guidewires into a major vein such as the cephalic or subclavian vein. An introducer sheath is advanced over one of these wires to allow insertion of the RV defibrillator lead, which is then positioned at the desired site within the right ventricle. Additional sheaths are then placed over the remaining guidewires to provide access for the LV and RA leads. To minimize the risk of the leads interfering with each other, these sheaths are typically left intact until all three leads are correctly positioned. The LV lead is guided into the coronary sinus using a specialized catheter, and coronary sinus venography may be performed to help identify the best target vein for LV lead placement. Once the LV lead is secured in a suitable lateral or posterolateral branch, the RA lead is positioned in the right atrium. Only after all leads are satisfactorily placed are the sheaths removed, and the leads are then sutured to the underlying tissue to prevent displacement. (Hadjis *et al.*, 2017)

In CRT-P procedures, a similar approach is used, but typically only two guidewires are needed initially. The RV pacing lead is positioned first, followed by the placement of the LV lead in

the coronary sinus and finally the RA lead. As with CRT-D, fluoroscopic guidance is essential throughout the procedure to ensure accurate lead placement and to avoid complications. Once all leads are in place, they are connected to the CRT device, which is then implanted beneath the skin, usually just below the collarbone. The device and leads are tested to confirm proper function before the procedure is completed.(Hadjis *et al.*, 2017)

2.6 Significance of HBP and LBBAP

Physiological pacing techniques such as His bundle pacing (HBP) and left bundle branch area pacing (LBBAP) have gained attention as alternatives to traditional right ventricular (RV) or biventricular pacing in cardiac resynchronization therapy (CRT), particularly because they directly engage the heart's native conduction system to restore synchrony and preserve natural electrical activation(Lustgarten *et al.*, 2015b). Both (Mizner *et al.*, 2022) and (Naqvi and Chao, 2023) highlight that HBP and LBBAP can more effectively maintain left ventricular synchrony, improve cardiac function, and lower the risk of pacing-induced cardiomyopathy compared to conventional RV apical pacing, and these methods are especially valuable in patients with challenging coronary venous anatomy or inadequate response to standard CRT.

The significance of HBP lies in its ability to achieve electrical resynchronization by pacing the His bundle, the main pathway for electrical conduction between the atria and ventricles. (Vijayaraman *et al.*, 2023a) highlight that HBP can correct bundle branch block and normalize QRS duration, leading to improved left ventricular function and symptomatic relief in patients with heart failure. This approach is especially valuable in patients who have failed conventional CRT or in whom left ventricular (LV) lead placement is not feasible due to anatomical constraints. HBP also minimizes the risk of pacing-induced dyssynchrony, a known complication of right ventricular pacing, by preserving the natural sequence of ventricular activation.

LBBAP, a more recent advancement, targets the left bundle branch or its immediate vicinity within the interventricular septum. As (Huang *et al.*, 2019a) explain, LBBAP offers a more consistent and lower pacing threshold compared to HBP and can be successfully performed even in patients with extensive conduction system disease. This technique has shown promising results in correcting left bundle branch block (LBBB) and achieving effective ventricular resynchronization, with studies reporting significant improvements in ejection fraction, heart failure symptoms, and overall quality of life. LBBAP is increasingly considered for patients who are not candidates for or have failed traditional CRT, as it bypasses the challenges associated with coronary sinus anatomy and LV lead placement.

The success of both HBP and LBBAP is closely linked to the development and use of specialized implantation tools and accessories. According to (Vijayaraman *et al.*, 2023c), the SelectSecure 3830 lead (Medtronic) has become the standard for HBP due to its small diameter, flexibility, and active fixation helix, which allows for precise placement within the His bundle region. The lead is delivered using a dedicated sheath system, such as the C315 His or C304 deflectable sheath, which provides the necessary support and manoeuvrability to navigate the right atrium and reach the His bundle. The use of electrogram mapping and fluoroscopic guidance is essential to confirm correct lead placement and achieve selective His bundle capture.

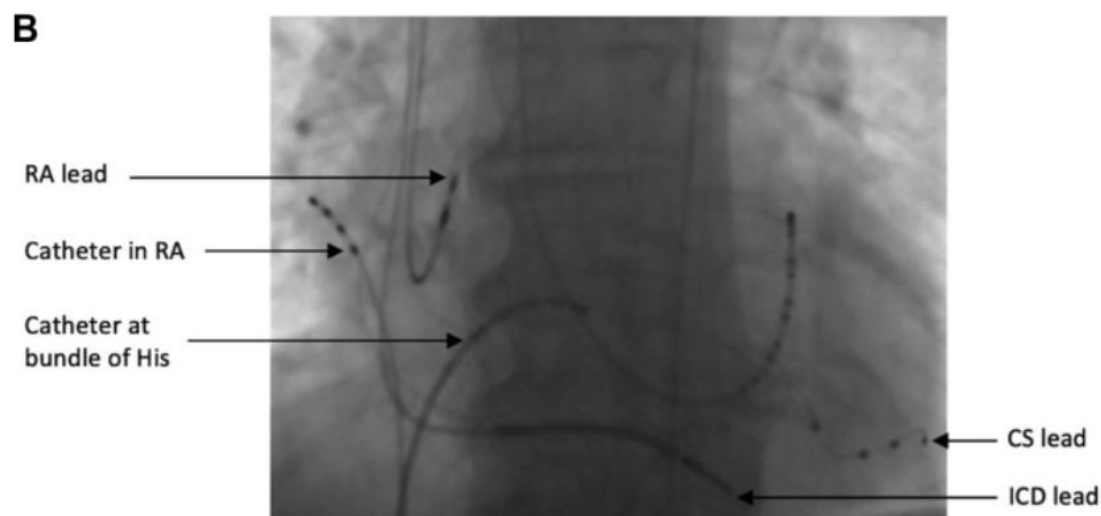


Fig 3: HBP lead placement fluoroscopy image. RA lead placed in right atrium, ICD lead placed in RV (CRT-Defibrillator Case), CS Lead in HIS area (HIS Bundle Pacing Lead). (Elliott *et al.*, 2020)

For LBBAP, the implantation technique involves advancing a pacing lead deep into the interventricular septum to capture the left bundle branch or its surrounding area. As described by (Vijayaraman *et al.*, 2023c), the same SelectSecure 3830 lead is commonly used for LBBAP, but the approach requires a slightly different technique. The lead is positioned at the right ventricular septum and then actively screwed through the septal tissue until electrical signals indicate capture of the left bundle branch. The C315 His or other steerable sheaths are also employed to facilitate accurate lead delivery and stability.



Fig 4: LBBAP Lead placement fluoroscopy image. RA lead placed in right atrium, ICD lead placed in RV (CRT-Defibrillator Case), CS Lead in Left Bundle Branch Area(Left Bundle Branch Area Pacing Lead via coronary sinus).(Elliott *et al.*, 2020)

In summary, HBP and LBBAP represent significant progress in the field of physiological pacing, offering effective alternatives to conventional CRT for patients with heart failure and conduction system disease. The use of dedicated leads, steerable sheaths, and advanced mapping technologies has been instrumental in the success of these techniques. As clinical experience and device innovation continue to grow, HBP and LBBAP are poised to play an increasingly important role in the management of cardiac dyssynchrony.

2.7 Comparative Evaluation of Pacing Performance Between His Bundle Pacing (HBP) and Left Bundle Branch Area Pacing (LBBAP) in Cardiac Resynchronization Therapy

Comparative studies have increasingly focused on the technical and electrophysiological performance of HBP and LBBAP, with a growing body of evidence favouring LBBAP in several key domains. A meta-analysis by (Zhuo *et al.*, 2022) produced data from seven clinical trials, encompassing 867 patients, to directly compare the pacing characteristics of HBP and LBBAP in the CRT population. Their findings revealed that LBBAP consistently achieved lower pacing thresholds at both the time of device implantation and during follow-up, with mean differences of 0.63 V/0.5 ms and 0.76 V/0.5 ms, respectively. Lower thresholds are clinically significant as they are associated with reduced battery drain and potentially longer device longevity. The authors attributed this superior threshold performance to the deeper and more stable lead positioning within the interventricular septum i.e., the characteristic of LBBAP, which likely facilitates more consistent engagement with the conduction system and myocardial tissue.

In addition to threshold performance, sensing capability is a critical determinant of pacing reliability. (Zhuo *et al.*, 2022) also reported that LBBAP leads generated significantly higher R-wave amplitudes than those observed with HBP, both at the point of implantation and during subsequent follow-up. Specifically, the mean difference in R-wave amplitude was 7.23 mV at implantation and 7.53 mV at follow-up, indicating robust and stable signal detection over time. This enhanced sensing is important for ensuring accurate detection of intrinsic cardiac activity and minimising the risk of under sensing, which can compromise device performance.

QRS duration, a significant factor for electrical synchrony, has also been evaluated in comparative studies. The same meta-analysis found that LBBAP was associated with a greater reduction in QRS duration during follow-up (mean difference: 6.12 ms), suggesting more effective ventricular resynchronization compared to HBP. Although immediate post-implant QRS narrowing did not differ significantly between the two techniques, the sustained improvement in QRS duration with LBBAP implies that its benefits may become more pronounced over time as ventricular remodelling occurs.

These findings are further supported by large-scale observational studies. (Tan *et al.*, 2023) examined over 300 patients and found that LBBAP not only maintained lower and more stable capture thresholds but also achieved higher R-wave amplitudes and greater lead impedance compared to HBP. Their analysis showed that patients with LBBAP were substantially more likely to achieve optimal device performance during follow-up, with a ninefold increase in the odds of optimal pacing parameters. This study also highlighted the consistency of LBBAP performance across a diverse patient cohort, reinforcing its reliability in routine clinical practice.

Additional research by (Molina-Lerma *et al.*, 2021) provided further evidence of the pacing advantages of LBBAP. In their comparative analysis, LBBAP resulted in narrower QRS complexes and more favourable pacing outcomes at both implantation and three-month follow-up. The stability of pacing parameters observed with LBBAP was notable, with fewer instances of threshold increases or sensing deterioration over time.

Electrophysiological mapping studies have also contributed valuable insights into the performance of these pacing modalities. (Ali *et al.*, 2023c) used non-invasive mapping to assess ventricular activation times in CRT recipients. Both HBP and LBBAP significantly reduced total and left ventricular activation times compared to biventricular pacing, with HBP providing a marginally greater reduction in total activation time. However, the improvements in left ventricular activation time and acute hemodynamic response were similar for both approaches, underscoring their shared ability to restore physiological activation patterns.

(Hua *et al.*, 2022) compared HBP, LBBAP, and biventricular pacing across multiple studies and found that both conduction system pacing strategies outperformed biventricular pacing in electrical resynchronization and myocardial work efficiency. LBBAP, in particular, demonstrated a slight advantage over HBP in terms of pacing parameters and QRS duration reduction, suggesting its potential as the preferred method for CRT in suitable candidates.

Recent studies employing advanced myocardial work assessment techniques have further differentiated the performance profiles of HBP and LBBAP. (Azzolini *et al.*, 2023) demonstrated that both modalities enhanced myocardial efficiency relative to native conduction, with LBBAP showing subtle differences in regional myocardial work distribution that may confer additional long-term benefits.

In summary, the evidence from meta-analyses, cohort studies, and electrophysiological investigations consistently indicates that LBBAP surpasses HBP in key pacing performance metrics. These include lower and more stable capture thresholds, superior sensing amplitudes, and greater QRS narrowing over time. Such advantages not only support the technical superiority of LBBAP but also suggest its potential for improved long-term device function and patient outcomes in CRT. Nevertheless, ongoing research and large-scale randomized trials remain essential to fully establish the clinical implications of these performance differences.

2.8 Safety and Feasibility

(Jastrzębski *et al.*, 2024) have provided substantial evidence supporting the feasibility of His Bundle Pacing (HBP) in routine clinical practice. They observed that HBP could be successfully achieved in the majority of patients requiring permanent pacing, with reported implant success rates ranging from 80% to 90% depending on operator experience and patient selection. Experience with (HBP) shows that procedural efficiency and implant success improve as operators gain familiarity with the technique, with these improvements levelling off after approximately 30 to 50 cases. (Jastrzębski *et al.*, 2024) further emphasize that while HBP is technically feasible in a wide range of patients, certain anatomical and electrical factors, such as septal fibrosis or advanced conduction system disease, can impact the likelihood of success. These findings indicate that, with appropriate training, patient selection and the use of specialized delivery sheaths and fixation leads, HBP can be reliably established in a broad patient population.

(Zanon *et al.*, 2019) conducted a large retrospective study to evaluate the long-term safety and technical performance of HBP. In their analysis of 844 patients, they found that HBP was associated with stable electrical parameters over a median follow-up of three years. The

majority of patients maintained acceptable pacing thresholds and sensing values, and freedom from pacing-related complications was observed in more than 91% of cases. The use of a fixed curve delivery sheath was linked to better electrical performance and lower complication rates compared to earlier delivery systems, underscoring the importance of technological advancements in improving HBP outcomes.

(Su *et al.*, 2021) have contributed important data on the feasibility and safety of Left Bundle Branch Area Pacing (LBBAP). In their studies, LBBAP was shown to be technically feasible in a high proportion of patients, with acute procedural success rates exceeding 90%. The procedure was associated with low and stable pacing thresholds and high R-wave amplitudes over follow-up. Complications such as lead dislodgement and septal perforation were rare, supporting LBBAP as a safe and reproducible alternative to conventional pacing.

(Padala *et al.*, 2020) undertook a prospective multicentre investigation to assess the safety and feasibility of left bundle branch area pacing (LBBAP) in patients requiring permanent pacemaker implantation. Their findings demonstrated that LBBAP could be successfully established in 89.4 % of the 341 patients enrolled, reflecting a high procedural success rate. The occurrence of major complications was notably low as only three patients experienced lead dislodgement, two within the first 24 hours and one at two weeks following the procedure. There were no instances of severe adverse events such as lead fracture or persistent septal perforation reported throughout the study period. These results indicate that, when performed by experienced operators, LBBAP is a safe and practical option for physiological pacing.

Studies show that both methods achieve high procedural success rates and have low complication risks, making them feasible choices for a wide range of patients. LBBAP, however, often provides procedural advantages, including higher implant success, more stable electrical parameters, and a lower incidence of lead related complications, especially in long-term follow-up. Current evidence suggests that while HBP and LBBAP are both reliable options, LBBAP is emerging as the preferred conduction system pacing approach due to its consistent safety profile and broader procedural applicability.

2.9 Predictors of Response

(Keene *et al.*, 2024) have shown that the immediate hemodynamic response to His Bundle Pacing (HBP) is a strong indicator of long-term clinical improvement in heart failure patients. In the analysis of the HOPE-HF trial, they found that patients who experienced marked acute increases in systolic blood pressure and cardiac output during HBP were more likely to demonstrate sustained benefits, such as enhanced exercise tolerance and improved quality of

life. This acute physiological response was a more reliable predictor of positive outcomes than traditional markers like baseline PR interval or echocardiographic E-A fusion, which did not consistently correlate with clinical success.

(Upadhyay *et al.*, 2020) have demonstrated that the degree of electrical resynchronization achieved by His bundle pacing is a critical predictor of response in CRT candidates. His research indicates that patients who exhibit substantial narrowing of the QRS complex after HBP implantation are more likely to experience meaningful improvements in left ventricular function and heart failure symptoms. Furthermore, the correction of bundle branch block patterns, particularly left bundle branch block, through successful His bundle capture is closely associated with favourable clinical outcomes. These findings highlight that both baseline QRS morphology and the ability of HBP to restore physiological ventricular activation are central determinants of a positive response to CRT delivered via His bundle pacing.

(Vijayaraman *et al.*, 2022) investigated factors predicting clinical and echocardiographic improvement following left bundle branch area pacing (LBBAP) in patients with heart failure undergoing cardiac resynchronization therapy. His results indicated that female patients and those who experienced a greater reduction in QRS duration after LBBAP were more likely to show significant improvements in left ventricular function and overall clinical status. The study emphasizes that both patient demographics and the extent of electrical resynchronization achieved during pacing are important determinants of a favourable response to LBBAP.

2.10 Gaps and Opportunities

Although numerous studies have explored pacing parameters and early clinical improvements there remains a notable lack of comprehensive data on long-term clinical outcomes following His bundle pacing (HBP) and left bundle branch area pacing (LBBAP). Specifically, outcomes related to heart failure hospitalizations, patient survival, device longevity, and overall quality of life are inconsistently reported or insufficiently addressed across the existing body of literature. This gap limits our ability to fully assess the sustained benefits and potential drawbacks of these advanced pacing techniques in real-world settings.

To address these limitations, the present qualitative study is designed to capture the perspectives and experiences of a diverse group of cardiac care professionals, including electrophysiologists, cardiologists, specialized nurses, and rhythm management technicians. Through the use of semi-structured interviews, the study aims to gather detailed insights into long-term patient outcomes, such as survival rates, frequency of hospital readmissions, device performance, and the impact on patients' daily lives after HBP and LBBAP implantation. These

qualitative accounts are invaluable, as they provide context and depth that are often absent from quantitative analyses, revealing nuanced patterns and practical challenges encountered in everyday clinical practice.

CHAPTER 3

3.1 Conceptual Framework

The conceptual framework guiding this study integrates the evolving landscape of cardiac resynchronization therapy (CRT), particularly focusing on the comparison between His bundle pacing (HBP) and left bundle branch area pacing (LBBAP) in terms of pacing performance, safety, feasibility, and predictors of response through qualitative exploratory study. At the core of modern heart failure management, CRT aims to restore coordinated contraction of the heart's ventricles, thereby improving cardiac output and alleviating symptoms in patients with ventricular dyssynchrony (Ponikowski *et al.*, 2016). While traditional biventricular pacing (BiV) has delivered significant clinical benefits, it is not without limitations, there is the risk of non-physiological ventricular activation and inadequate response in a notable proportion of patients (Ali *et al.*, 2023a).

Recognizing these gaps, recent innovations in conduction system pacing have led to the development of HBP and LBBAP, both of which are designed to mimic the heart's intrinsic electrical conduction (Vijayaraman *et al.*, 2021). HBP directly stimulates the His bundle, preserving physiological conduction and ventricular synchrony (Lustgarten *et al.*, 2015b). On the other hand, LBBAP targets the left bundle branch within the interventricular septum, enabling natural and efficient left ventricular activation even in cases of proximal conduction block (Huang *et al.*, 2019b). This distinction is meaningful because LBBAP, by bypassing proximal conduction barriers, may ensure more consistent electrical synchrony and overall procedural success, especially in patients with complex conduction system disease (Vijayaraman *et al.*, 2023b).

This study's hypothesis centres on the perception, growing among clinicians, that LBBAP delivers superior pacing outcomes when compared to HBP. Attributes such as lower and more stable pacing thresholds, improved sensing (as measured by R-wave amplitudes), and enhanced ventricular resynchronization contribute to this perception. Meta-analyses and comparative trials, for instance, have shown that LBBAP achieves lower capture thresholds at both implantation and follow-up, as well as significantly stronger sensing amplitudes, suggesting a more energy efficient device-tissue interface (Zhuo *et al.*, 2022) (Vijayaraman *et al.*, 2023a). At the same time, the relative reduction in QRS duration under LBBAP indicates a greater degree of electrical coordination, an effect that becomes especially pronounced with extended follow-up (Ali *et al.*, 2023c).

Evaluating CRT through this lens requires not only an analysis of device and procedural variables, but also a deep understanding of individual patient characteristics and context.

Factors such as baseline QRS duration, ejection fraction, duration and severity of heart failure, and the degree of mechanical synchrony have been shown to influence the likelihood of a favourable CRT response(Parikh *et al.*, 2022). Optimal patient selection and timely intervention, along with precise lead placement and technique, are therefore crucial, and differences between HBP and LBBAP may become more or less consequential depending on these clinical variables(Vijayaraman *et al.*, 2023b).

Another pillar of this framework is the real-world applicability of CRT strategies. While clinical trials and meta-analyses offer standardized, controlled insights, they often fall short of capturing long-term patient outcomes like heart failure rehospitalization, device longevity, and quality of life(Pothineni *et al.*, 2022). Therefore, this study incorporates a qualitative dimension, seeking input from electrophysiologists, cardiologists, EP Lab and CCU nurses, and device technicians through interviews. Their perspectives provide a richer picture of practical challenges, complication management, and unmet needs, situating the study's findings within the broader context of actual clinical practice.

The study is thus organized around three principal objectives; to clarify practitioner experiences and perceptions regarding device performance and procedural outcomes with HBP and LBBAP; to assess the safety and feasibility of each technique in real-world practice; and to identify both clinical predictors that guide optimal technique selection. This multi-layered approach is reinforced by an interpretivist philosophical stance, which values the lived experience and expert judgment of healthcare professionals and aims to generate actionable knowledge that bridges clinical research and day-to-day patient care(Saunders *et al.*, 2019a).

In summary, the conceptual framework positions HBP and LBBAP as competing but complementary innovations in CRT, with an emphasis on physiological pacing, clinical efficacy, safety, and patient-centred outcomes. By integrating quantitative findings from the literature with qualitative insights from practitioners, the framework provides a robust foundation for evaluating conduction system pacing in heart failure and guiding future research and clinical practice decisions.

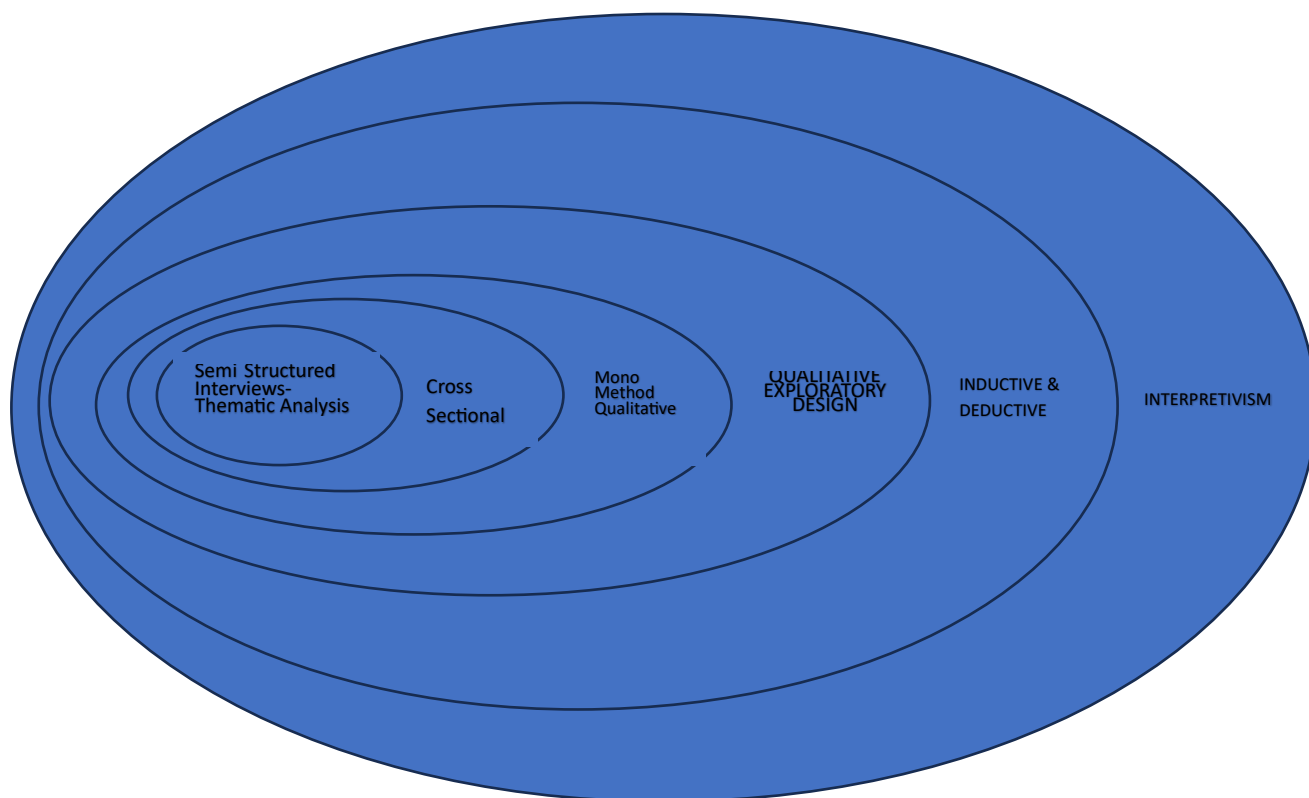


Fig 1: *The Research Onion adapted for this study, illustrating the layered methodology: from an interpretivist philosophical stance and inductive approach, through qualitative exploratory strategy and mono-method choice, to cross-sectional data collection using semi-structured interviews and thematic analysis (adapted from Saunders et al., 2019).*

3.2 Research Philosophy

This research adopts a qualitative exploratory design, grounded in an interpretivist philosophical framework, to investigate the comparative pacing performance, safety, feasibility, and clinical decision-making surrounding His Bundle Pacing (HBP) and Left Bundle Branch Area Pacing (LBBAP) in cardiac resynchronization therapy (CRT). The interpretivist perspective is particularly suitable for this work, as it facilitates a nuanced understanding of healthcare professional's lived experiences and the complex contexts that influence the adoption and outcomes of advanced pacing strategies in routine cardiac care (Saunders et al., 2019a).

Unlike positivist research, which focuses on objective metrics and universal laws, interpretivism emphasizes the subjective meanings and contextual factors that shape clinical choices (Creswell and Poth, 2017). CRT techniques continue to evolve, and the expertise, perceptions, and decision-making processes of practitioners play a crucial role in determining which method is chosen and how it is implemented. By concentrating on the perspectives of those directly involved in CRT delivery, including electrophysiologists, cardiologists, cardiac

nurses, and rhythm technicians, this design enables a holistic exploration of both technical and experiential aspects that can be underrepresented in quantitative clinical research.

3.3 Research Approach

A mixed approach of both deductive and inductive forms the foundation of this study's methodology. This research aims to develop insights and patterns that emerge directly from practitioner accounts and contextual realities. This 'bottom-up' logic allows new frameworks to arise organically as clinicians describe the intricacies, barriers, and clinical judgments unique to their practice environments (Creswell and Poth, 2016).

The deductive approach will be used as some perspectives of the clinicians can be straight forward with the research questions. The inductive approach is used here because the field of conduction system pacing is rapidly evolving and complex, with real-world clinical practice often diverging from established theory. By using inductive reasoning, this research allows cardiac care experts lived experiences and problem-solving strategies to shape the findings organically.

3.4 Research Strategy

This primary research strategy is fundamentally qualitative and exploratory. Employing qualitative research enables the capture of complexities and practical perception that quantitative measures alone often overlook (Lyons *et al.*, 2024). Through open, flexible explorations; rather than rigid protocols; the study seeks to understand the evolving landscape of CRT practice, mapping both strategic and practical decision factors for HBP and LBBAP use.

3.5 Methodological Choice

The primary methodological approach involves conducting semi-structured interviews with a purposively sampled group of cardiac care professionals who have direct, practical experience with both HBP and LBBAP. This strategy ensures that the research captures real-world expertise and covers a diverse range of insights reflecting different professional backgrounds, levels of seniority, and institutional practices. Eligible participants must have at least one year's experience with CRT device implantation and follow-up, ensuring that responses are informed by practical knowledge rather than theoretical familiarity. The study aims to recruit between ten and fifteen participants.(Saunders *et al.*, 2019b).

Each interview will follow a flexible guide informed by the research objectives and the conceptual framework of the study. Topics will include procedural considerations, challenges and complications, predictors of therapeutic response, and comparisons of day-to-day pacing

outcomes with HBP versus LBBAP. This format allows for consistency while also permitting participants the flexibility to explore concepts and issues they find most relevant or impactful. Interviews will be audio-recorded, transcribed verbatim, and anonymized to preserve confidentiality.

3.6 Time Horizon

The study utilizes a cross-sectional design, capturing a detailed perception of current practice at a well-defined point in time. This approach is particularly suitable for investigating prevailing practice, strategies, and outcomes in the context of rapidly advancing CRT technologies and protocols.

3.7 Data Collection and Analysis

3.7.1 Sampling and Recruitment

Participants for this study were drawn from my network of former colleagues, accumulated through my prior experience as a cardiac rhythm management technician. This approach provided direct access to a group of skilled professionals; electrophysiologists, cardiologists, EP Lab and CCU nurses, and device technicians; who have substantial; hands-on experience with CRT device implantation and management. Because I had previously worked alongside these individuals, there was an established sense of trust and professional familiarity, which encouraged honest, detailed discussions during the interviews. The sample size is 10-15 interviews, ensuring that all significant themes and perspectives are captured.

Each participant was actively involved in cardiac device therapy, possessing more than a year of practical exposure to both conduction system pacing techniques. Their varied roles ensured that the sample reflected a comprehensive range of viewpoints covering not only procedural and decision-making aspects but also perioperative care and technical troubleshooting.

For recruitment, I reached out directly to these contacts via personal messages, providing information about the nature and aims of the study and inviting them to participate on a voluntary basis. This targeted strategy helped secure participation from practitioners across different clinical settings and levels of seniority, maximizing the diversity and relevance of insights for the qualitative analysis.

3.7.2 Interview Process

Semi-structured interviews were conducted using online platforms to facilitate flexible and in-depth discussions. The interview guide was carefully developed with direct reference to the three core objectives of the research, ensuring that questions effectively captured relevant aspects of conduction system pacing from multiple professional perspectives.

Each participant group; electrophysiologists, cardiologists, nurses (EP Lab and CCU), and cardiac rhythm management technicians; was provided with a tailored set of questions designed to explore their specific roles and experiences. For example, electrophysiologists and cardiologists were asked about procedural selection criteria, technical challenges, and long-term outcomes relating to HBP and LBBAP; nurses were questioned on patient care and complication monitoring; technicians focused on device programming and follow-up monitoring.

All interviews were audio-recorded with consent, transcribed verbatim, and anonymized. Questions included procedural considerations, complication management, predictors of patient outcomes, and comparative clinical experiences, aligning closely with the study objectives. This semi-structured format allowed for both consistency across interviews and flexibility for participants to discuss issues most pertinent to their clinical practice, thereby enriching the qualitative data gathered.

3.7.3 Data Handling

All data are stored in encrypted, password-protected locations with limited access; identifiable information is removed prior to analysis.

3.7.4 Analysis

Data derived from the interviews will be analysed using thematic analysis as outlined by Braun and Clarke (Braun and Clarke, 2006). The analysis will begin with an in-depth familiarization stage, where transcripts are read repeatedly to gain a comprehensive understanding of the content. The next step involves generating initial codes by labelling important pieces of information related to the study's aims. These codes will be organized and generated manually to accurately reflect meaningful elements throughout the transcripts.

Following coding, the codes will be grouped into preliminary themes that represent significant patterns or concepts in the data. These candidate themes will then be carefully reviewed and refined to ensure they accurately capture the data and are coherent and distinct from each other. Finally, the thematic findings will be woven together into a narrative that addresses the research questions and objectives. The process is flexible and iterative, allowing movement between stages as needed to deepen understanding and refine results. Thematic analysis is well suited to qualitative medical research, as it enables both in-depth exploration and broad pattern identification while ensuring that practitioner voices are central to the final narrative (Nowell *et al.*, 2017).

3.8 Ethical Considerations

Ethical integrity is maintained throughout the research process. All participants receive a participant information letter that clearly explains the study's purpose, procedures, and how their data will be used and protected. Prior to participation, individuals are asked to provide informed consent by signing a consent form, confirming their voluntary agreement to take part. Data privacy is prioritized through secure storage and anonymization protocols. The research is overseen and approved by the relevant institutional ethics committee, and all research activities are conducted in accordance with established ethical guidelines.

CHAPTER 4

4.1 Introduction

This chapter presents the findings of the qualitative component of this study, which explored in depth and real-world perspectives of electrophysiologists, cardiologists, EP lab Nurses, cardiac care unit (CCU) nurses and cardiac rhythm management technicians on the use of conduction system pacing (CSP) modalities; specifically, His Bundle Pacing (HBP) and Left Bundle Branch Area Pacing (LBBAP); within Cardiac Resynchronization Therapy (CRT) practice. The purposes of this chapter are to present a detailed analysis of participant perspectives, showing how they evaluate and compare these techniques in terms of pacing performance, patient response, safety, feasibility and to link these themes to the current evidence base through structured comparison with the literature review presented in Chapter 2.

4.2 Overview of the Interview Dataset

The findings draw on 14 semi-structured interviews conducted with 4 electrophysiologists, 3 cardiologists, 2 EP lab and 2 cardiac care nurses and 3 technicians actively involved in implanting, programming, and monitoring CRT devices using HBP and LBBAP. The interviewees represented a range of professional experience levels and clinical settings but all had direct procedural expertise. Interviews were conducted individually ensuring coverage of the main research objectives.

Participants provided detailed reflections on multiple aspects of CRT delivery. These included clinical and anatomical factors affecting the choice between HBP and LBBAP, procedural workflows and technical complexity, electrical performance metrics such as pacing thresholds and QRS narrowing, long-term stability of device function, complication risks, and the patient characteristics that influence CRT outcomes. Importantly, interview captured both technical insights; such as mapping strategies, sheath selection, and septal penetration; and patient-focused considerations, including tolerance of procedures in frail individuals.

The complete interview content demonstrated a high degree of technical specificity, interwoven with real-world practical decision-making. The interviews provided rich analysis of why certain strategies succeed or fail in different contexts, creating a robust qualitative evidence base for thematic analysis.

Coding the data was mixed approach, deductive and inductive, allowing the themes to emerge from the data without relying on pre-determined categories. This grounded approach ensured the final themes remained faithful to the real priorities, language, and experiences of participants.

4.3 Example of Theme Emergence

A notable example of inductive theme development in this study is the emergence of “reproducibility” and the “learning curve” as key factors influencing real-world practice. Although the initial coding framework was organized around pre-specified objectives such as pacing performance and procedural safety, repeated references from participants to the straightforwardness, consistency, and increasing ease of LBBAP implants led to new, unexpected thematic connections. For instance, electrophysiologists described LBBAP as “more straightforward and consistent after initial training,” and reflected that procedural challenges “reduced significantly as the learning curve was overcome.” In contrast, HBP was repeatedly characterised as technically demanding, with interviewees highlighting the persistent need for “meticulous mapping and fine sheath manipulation” and reporting “prolonged procedures or sometimes result in failure” when anatomical conditions were not optimal.

4.4 Participant Perspectives on Pacing Performance of His Bundle Pacing (HBP) and Left Bundle Branch Area Pacing (LBBAP) in Cardiac Resynchronization Therapy (CRT)

4.4.1 Thematic Overview of Participant Perspectives on Pacing Performance

Participant reflections include several key themes related to electrical performance characteristics and procedural outcomes: sensing amplitudes, ventricular activation patterns indicated by QRS duration, pacing threshold stability, and technical challenges in achieving effective capture. These themes emerged from an inductive thematic analysis integrating the views of electrophysiologists, cardiologists, specialized nursing staff and technicians.

4.4.2 Sensing Amplitudes and Signal Reliability

All participants across the clinical and technical spectrum agreed that LBBAP consistently delivers higher and more stable sensing amplitudes compared to HBP, a key factor influencing device functionality and patient safety.

Electrophysiologists frequently emphasized the physiological basis for this observation. One noted that LBBAP’s septal lead placement engages a larger myocardial mass, generating stronger and more reliable R-wave signals essential for precise device pacing and sensing. Two electrophysiologists recounted clinical scenarios where HBP sensing was borderline or variable, sometimes complicating device programming and risking inadequate capture. This was echoed by cardiologists, who linked robust sensing with improved long-term pacing consistency and patient outcomes.

Nursing staff contributed operational perspectives, highlighting how sensing stability facilitates routine device interrogation and remote monitoring in LBBAP. The ability of LBBAP to consistently detect appropriate signals reduces false alarms and the need for frequent adjustments, improving both patient safety and workflow efficiency.

Technicians provided a complementary viewpoint focusing on intraoperative and follow-up device management. They observed that LBBAP leads yielded cleaner and more stable electrocardiographic signals during implantation and device interrogation. This smoothed programming, reduced troubleshooting time, and minimized patient procedure duration. In contrast, HBP required repeated threshold checks and occasional repositioning due to signal variability. A Technician stated LBBAP yields “*stronger and more reliable R-wave sensing*” for easier programming and follow-up.

These experienced-based perspectives align with Chapter 2 literature, where (Huang *et al.*, 2019b) and (Vijayaraman *et al.*, 2021) specifically point to LBBAP’s anatomical engagement of the left bundle area as the source of higher sensing amplitudes and enhanced electrical contact, supporting the uniformly positive clinical experience reported.

4.4.3 Ventricular Activation and QRS Duration

Participants across all groups agreed that both HBP and LBBAP achieve narrower QRS durations compared to conventional biventricular pacing, indicative of improved ventricular synchrony. However, the consensus favoured LBBAP for its greater reproducibility and consistency across diverse clinical cases.

Electrophysiologists described how LBBAP reliably produces narrow and stable QRS complexes, which translated to more physiological electrical activation. One electrophysiologist reflected, “*LBBAP has outperformed HBP in all pacing characters in my CRT cohort. Lower and steadier pacing thresholds, high and sustained sensing amplitudes, and clear and narrow QRS complexes have made it my preferred technique over time.*”

Cardiologists repeated these observations, correlating narrower QRS with improved left ventricular function and symptomatic gains in their patients. Another Electrophysiologist stated that “*Ejection fraction improvements are also significant for both, but sustained improvements are more likely with LBBAP due to its stable electrical parameters.*”

Nurses noted that reviewing ECG tracings during follow-up simplify the monitoring process and reduce the need for frequent device reprogramming. Technicians also highlighted that electrocardiographic consistency with LBBAP allows for cleaner device signal detection and fewer adjustments compared to HBP cases where QRS variations sometimes raised concerns.

Literature reviewed in Chapter 2 backs clinical feedback (Ali *et al.*, 2023b) and (Lustgarten *et al.*, 2015b) affirm that both HBP and LBBAP yield more physiological ventricular activation than BiV pacing, but (Huang *et al.*, 2019a) emphasize that LBBAP's method of activating the left bundle branch directly often leads to more reproducible and narrower QRS durations. These findings resonate with operator experiences describing LBBAP as a more dependable option in complex or scarred hearts.

4.4.4 Pacing Threshold Stability and Long-Term Lead Capture

Maintaining low and stable pacing thresholds emerged as a critical clinical advantage of LBBAP across participant groups. Stable thresholds contribute directly to device longevity, patient safety, and sustained therapeutic benefit.

Electrophysiologists consistently stated that LBBAP capture thresholds tend to remain low and stable over extended follow-up periods, often beyond 12 months. A nurse remarked “*HBP lead placement is more technically demanding, so we often spend longer time assisting with fine adjustment and testing. His bundle area is small, making lead fixation delicate and sometimes unstable, which results in frequent threshold testing during the procedure. And troubleshooting capture issue or repositioning the lead is more common in HBP, requiring patience and close coordination with physicians.*” Cardiologists agreed, linking threshold stability of LBBAP to long-term clinical improvements and fewer device related complications.

Nurses described observing fewer pacing failures and lead issue events in patients paced with LBBAP, while technicians emphasized smoother device interrogations and decreased need for alarm management due to stable electrical parameters.

The literature similarly acknowledges HBP's challenges with threshold instability, as noted by (Vijayaraman *et al.*, 2021) and (Huang *et al.*, 2019a). In contrast, (Huang *et al.*, 2019b) states that LBBAP is documented to have consistent and low thresholds attributed to its broader septal lead interface and effective engagement of the conduction tissue, affirming the frontline clinical advantages reported by study participants.

4.4.5 Technical Challenges and Procedural Considerations

All participant groups highlighted significant differences in the technical demands and procedural workflows associated with HBP and LBBAP implantation.

Electrophysiologists generally agreed that HBP implantation is technically demanding due to the small size of the His bundle region and the need for precise mapping and lead positioning. Several clinicians described the necessity of careful sheath manipulation and repeated attempts

to secure effective His capture, often complicated by septal fibrosis or poor signal detection. Procedure times were frequently longer, and risk of lead dislodgment is higher.

But, LBBAP was described as significantly more reproducible once the initial learning curve is overcome. The broader target area within the septum and newer delivery tools contribute to higher implant success rates and shorter fluoroscopy exposure. Nevertheless, participants cautioned about the importance of confirming true left bundle capture and avoiding septal or left ventricular perforation, calling for vigilant imaging support during implantation.

Nurses emphasized greater attentiveness and preparation during HBP cases given the complexity and multiple repositioning, whereas with LBBAP, the intraoperative workflow was smoother but required careful management to prevent septal trauma. Technicians added critical perspective on device setup, noting that HBP procedures often involved extensive real-time adjustments and device testing, increasing procedural length and complexity. Conversely, they found LBBAP interventions more streamlined, contributing to enhanced procedural efficiency and patient tolerability.

This multidisciplinary feedback aligns tightly with the insights from (Ali *et al.*, 2023a), (Huang *et al.*, 2019a), and (Vijayaraman *et al.*, 2021), who documented the steep learning curve of HBP as well as the broader accessibility and reproducibility of LBBAP in routine practice.

4.4.6 Comparison to Literature

This rich participant experience supports the scientific consensus outlined by (Lustgarten *et al.*, 2015b), (Huang *et al.*, 2019a), (Vijayaraman *et al.*, 2021), and (Ali *et al.*, 2023a). Their combined clinical and research data affirm that LBBAP represents a versatile, reliable, and patient friendly advancement in CRT pacing, capable of addressing many limitations of both conventional BiV and His Bundle pacing technique.

4.4.7 Summary

The convergence of perspectives from electrophysiologists, cardiologists, nurses, and technicians states a comprehensive and consistent picture: while both HBP and LBBAP improve cardiac resynchronization by more physiological ventricular activation than traditional BiV pacing, LBBAP is increasingly recognized as superior in terms of sensing reliability, QRS narrowing consistency, pacing threshold stability, and procedural practicality. All participant groups emphasized that LBBAP's anatomical and electrical advantages translate into more consistent clinical outcomes and ease of device management. The more selective applicability of HBP, coupled with its technical challenges and threshold variability, limits its

role primarily to cases with preserved His-Purkinje anatomy where precise atrioventricular synchrony is critical.

In summary, the detailed, multidisciplinary insights presented here illustrate the evolving landscape of conduction system pacing in CRT, underscoring the growing dominance of LBBAP as the preferred modality for optimized ventricular resynchronization and patient outcomes, while recognizing continuing roles for HBP in carefully selected clinical scenarios. This integration of frontline practitioner knowledge with rigorous literature review strengthens the foundation for continued refinement and personalization of CRT therapy.

4.5 Safety and Feasibility of His Bundle Pacing (HBP) and Left Bundle Branch Area Pacing (LBBAP) in Cardiac Resynchronization Therapy (CRT)

4.5.1 Procedural Feasibility and Acute Success Rates

Electrophysiologists reported that while both HBP and LBBAP are feasible, LBBAP was commonly perceived as more reproducible and widely applicable across varied anatomical scenarios. Initial success with HBP was highly dependent on ideal His-Purkinje system anatomy and the absence of significant septal fibrosis. Some described the difficulty of achieving and maintaining stable His bundle capture, noting that HBP often required meticulous mapping and extended procedure times; especially in the presence of prior leads or challenging venous access. In contrast, LBBAP's broader septal target was credited for easier initial learning, reduced mapping time, and higher immediate success rates. One electrophysiologist stated, *"With LBBAP, the procedures rapidly become more reproducible after initial training. So, the technique involves septal tunnelling and the most important challenge is confirming the true left bundle capture while avoiding septal or the LV perforation. So, in my experience, LBBAP now has a higher overall success rate and faster procedure times."*

Cardiologists supported these procedural impressions, emphasizing that LBBAP had largely supplanted HBP as their preferred option. Several indicated that early failures with BiV or HBP; often due to venous anomalies or high thresholds; could overcome reliably by crossing over to LBBAP, which presented fewer anatomical limitations.

Technicians highlighted the operational benefits of LBBAP, describing more straightforward device setup, fewer real-time troubleshooting steps, and shorter fluoroscopy times. Nurses echoed this, noting that LBBAP generally reduced procedural stress for both patients and staff due to decreased instrument changes and lower risk of lead repositioning. Procedural times for LBBAP were frequently described as shorter and more consistent than for HBP.

4.5.2 Complication Profiles and Long-Term Safety

Lead revisions and capture threshold rises surfaced as primary safety concerns with HBP. One electrophysiologist stated that, HBP carries a higher risk of acute and chronic lead dislodgement as well as a gradual increase in pacing thresholds. So, it's necessitating more frequent surveillance or even re-intervention. In contrast, LBBAP was almost unanimously described by all participant groups as demonstrating lower, more stable capture thresholds and very infrequent need for lead revision or repositioning.

Incidence of major complications; such as lead dislodgement or septal perforation; was reported as low for both modalities when performed by experienced operators. Nonetheless, initial experiences with LBBAP included sporadic cases of acute septal irritation or minor perforation, all resolving with lead adjustment. As procedural expertise matured, complication rates were said to decrease further.

Nursing staff emphasized that HBP required more intense intraoperative monitoring for loss of capture, bradycardia, or adverse patient symptoms, as threshold fluctuations could occur abruptly. Nurses and technicians stated that LBBAP's more predictable electrical behaviour reduced the need for emergency interventions. Device technicians noted fewer complications related to sensing artifacts and repeated interrogation alarms, improving overall patient safety in the follow-up period for LBBAP.

4.5.3 Reproducibility and Learning Curve

A strong theme emerging across all professional roles was the importance of procedural reproducibility. While initial adopters found both techniques challenging, nearly all participants stated that the learning curve for LBBAP was shorter and plateaued at a higher level of initial success. Technical limitations for HBP; such as the need for meticulous mapping, narrow target area, and susceptibility to dislodgement; meant that even experienced operators sometimes struggled to reproduce initial success. LBBAP, by contrast, was described by an electrophysiologist as *"And with LBBAP, the complication profile has been similar to standard RV pacing, but after the initial 10 to 20 cases, with only a rare instance of intraventricular septal hematoma, all managed conservatively, you know."*

Technicians and nurses highlighted that greater reproducibility with LBBAP translated to more efficient teamwork, predictable case planning, and fewer emergency interventions. Both groups indicated that increasing institutional experience universally reduced both complications and average procedure duration of LBBAP.

4.5.4 Suitability for High-Risk, Elderly, and Complex Cases

There was a clear, shared viewpoint that LBBAP is better suited for high-risk cohorts; those who are elderly, frail, or have extensive comorbidities. One cardiologist explained that shorter, more predictable procedure times reduce perioperative risk for patients with marginal hemodynamic stability. Electrophysiologists underlined that complex anatomical cases; such as those with failed CRT attempts, dilated cardiomyopathy or poor His signal; were far more feasible with LBBAP.

Nurses and technicians emphasized that vulnerable patients require the least invasive, most reliable strategy possible, and LBBAP meets these needs more consistently due to its procedural efficiency and predictable follow-up requirements. They all reported that LBBAP led to faster post-procedural recovery in elderly or otherwise compromised patients.

4.5.5 Comparison to Literature

Secondary research supports these clinical impressions. As detailed in Chapter 2, (Su *et al.*, 2021) and (Padala *et al.*, 2020) report that LBBAP is technically feasible in over 90 % of cases, with low and stable pacing thresholds and high R-wave amplitudes on follow-up. For LBBAP, acute and medium-term complication rates; including lead dislodgement and septal perforation; are rare and decline further once the operator learning curve is achieved. In contrast, while HBP provides physiological ventricular activation, studies of (Zanon *et al.*, 2018) and (Jastrzębski *et al.*, 2024) highlights persistent technical hurdles such as threshold instability, loss of selective His capture, and the need for system revision in a proportion of patients. These limitations are among the most frequently cited barriers to broader HBP adoption in routine CRT practice.

4.5.6 Summary

The combined insights of electrophysiologists, cardiologists, nurses, and technicians indicate that LBBAP is, in most cases, a safer and more feasible option than HBP for current CRT practice, owing to its greater reproducibility, lower complication rates, shorter procedure times, and wider anatomical suitability. While HBP still holds significant value in carefully selected patients with favourable conduction system anatomy where achieving physiologic synchrony is particularly important, its broader use is limited by technical challenges and safety concerns. The consensus across disciplines emphasizes LBBAP's practical and patient-focused benefits, especially in elderly, complex, or higher-risk individuals. These professional experiences are consistent with the published evidence, which supports the growing adoption of LBBAP as the preferred physiological CRT approach, with HBP reserved for more specific indications.

4.6 Predictors of Response

In the context of CRT through conduction system pacing, predictors of response are the clinical, demographic, technical, and procedural factors that can indicate whether a patient is likely to experience sustained improvement in cardiac function and symptoms. In clinical practice, these predictors guide pacing modality selection, influence procedural strategy, and inform expectations about long-term benefit. In this study, participants repeatedly returned to the notion that certain changes seen intra-procedurally; such as acute QRS narrowing, low capture thresholds, or strong sensing signals; often foreshadow durable success. These technical indicators were seen within a wider framework that also considered baseline patient characteristics, for example, conduction system integrity, comorbidity burden, and anatomical complexity; as essential in shaping outcomes.

The perspectives here draw on the collective experience of electrophysiologists, cardiologists, nurses, and technicians, and are presented according to the thematic structure from the analysis: immediate electrical outcomes, procedural and technical metrics, patient-related background factors, and long-term clinical performance. These insights align closely with the evidence reviewed in Chapter 2, where studies such as *Keene et al. (2024)*, *Upadhyay et al. (2020)*, and *Vijayaraman et al. (2022)* link acute procedural markers and patient characteristics to CRT effectiveness.

4.6.1 Immediate Electrical Outcomes as Predictors

One of the most consistently cited indicators of likely CRT response was the degree of acute electrical resynchronization achieved during implantation, particularly in the form of QRS narrowing. An Electrophysiologist emphasised the difference observed with conduction system pacing, explaining: “In terms of ventricular activation, both offer significantly narrower paced QRS durations than biventricular pacing, but LBBAP’s QRS is frequently even narrower and more reproducible in practice.” The notion of reproducibility; the ability to achieve and maintain this narrowing consistently was seen as central to anticipating success.

As per the Cardiologists, the link between the electrical synchrony and clinical outcomes was direct: “LBBAP’s wider capture area and lower pacing thresholds allow it to maintain tighter electrical synchrony in more patients, resulting in improved and stable LVEF gains over months.” Here synchrony was not just an electrocardiographic phenomenon, but a measurable determinant of long-term left ventricular function.

Another Electrophysiologist drew attention to situations where this reproducibility proved particularly important: “*The QRS duration is comparable between HBP and LBBAP, but I have*

found LBBAP more reliable, especially in difficult cases or scar tissue.” This underscores the view that achieving a reproducibly narrow QRS, even in unfavourable myocardial substrates, is a stronger predictor of response.

In the literature, (Upadhyay *et al.*, 2020) found that in CRT patients, those with a substantial narrowing of the QRS complex after HBP implantation were more likely to achieve significant improvement in LVEF and symptoms. Similarly, (Vijayaraman *et al.*, 2021) observed that greater reductions in QRS duration following LBBAP predicted meaningful gains in left ventricular function. These findings match the clinician emphasis on QRS change as a primary procedural predictor.

4.6.2 Procedural and Technical Metrics as Predictors

For many participants, the stability of pacing parameters achieved at implantation was equally important in predicting a patient’s long-term success. An Electrophysiologist described their experience in straight forward terms: *“See, like LBBAP consistently provides lower and more stable pacing thresholds, often well below 1 volt at implant and maintained over follow-up, even 12 months beyond. So, sensing amplitudes are also generally higher.”* The sustained nature of these low thresholds was contrasted with HBP’s tendency toward variability.

From Cardiologists perspective, such stability had direct clinical implications, *“Yet, LBBAP patients tend to experience more durable benefits likely because the pacing thresholds remain low and ventricle activation times are shorter and more physiologic.”* Here, threshold stability is framed as a mechanism for preventing deterioration in ventricular function over time.

An Electrophysiologist outlined another technical factor: *“Coming to the LBBAP, its pacing thresholds are lower and stable and sensing is superior due to the deeper septal placement and the robust ventricular engagement.”* Robust sensing was tied to device reliability and patient safety, as it facilitates accurate intrinsic rhythm detection.

By contrast, unstable thresholds in HBP were seen as a negative predictor. As the Electrophysiologist noted: *“sporadic threshold increases or sometimes loss of capture over time.”* Such events will lead to lead revision or loss of effective resynchronization.

These accounts mirror the literature in Chapter 2, where (Zanon *et al.*, 2018) reported that threshold rises or loss of His capture frequently preceded revisions in HBP patients. In contrast, (Su *et al.*, 2021) and (Padala *et al.*, 2020) documented consistently low thresholds, high R-wave amplitudes, and minimal revision rates for LBBAP, confirming that these intra-procedural and early post-implant measures are linked to long term success.

4.6.3 Patient-Related Predictors

Beyond the procedure itself, participants considered certain patient characteristics as shaping the likelihood of a positive response. These included age, frailty, comorbidities, and anatomical considerations.

An Electrophysiologist reflected on the role of frailty: *“So in elderly or frail patients, LBBAP’s procedural reproducibility and safety profile are also significant advantages.”* In this way, patient health was integrated into the choice of modality as part of the response prediction process.

Another Electrophysiologist drew attention to complex cases: *“And in patients with previous failed CRT attempts, dilated cardiomyopathy, or poor health signals, LBBAP is usually selected for its technical ease and predictable capture characters.”* Implication is clear, feasibility of implantation and early capture stability in such anatomically challenging cases are themselves predictors of long-term response.

4.6.4 Long-Term Clinical Performance as a Predictor

Cardiologists, in particular, emphasised long term performance as both the ultimate test of response and something that can often be foreseen during or soon after implantation. A Cardiologist summarised this link, *“I observe that both modalities significantly enhance cardiac function versus standard CRT, with marked improvements in ejection fraction and symptomatic status. Yet, LBBAP patients tend to experience more durable benefits, likely because the pacing thresholds remain low and ventricular activation times are shorter and more physiologic.”* In this account, the procedural and technical successes seen are explicitly tied to durable clinical improvement.

Similarly, a Cardiologist described, *“However, left bundle pacing’s wider capture area and lower pacing thresholds allow it to maintain tighter electrical synchrony in more patients, resulting in improved and stable LVEF gains over months.”* Such sustained benefits were seen more often with LBBAP, which participants associated with both acute procedural success and long-term stability.

Predictor	LBBAP	HBP
Narrow QRS	Narrow QRS, highly reproducible, even in complex or scarred tissue	Can narrow QRS in ideal cases; less consistent across diverse anatomies
Threshold & Stability	Low, very stable	Higher, may rise over time
Sensing Amplitude	High amplitude, reliable	Lower, may be unreliable
Procedure Feasibility	High, simpler technique	Challenging, less predictable
Patient Suitability	Wider range of patients	Specific subset
Long-Term Response	Strong clinical confidence	Some concern, less robust

Table 1. Comparison of Predictors of Response for LBBAP and HBP Based on Interview Finding

4.6.5 Summary

In summary, predictors of CRT response via conduction system pacing, as described by the multidisciplinary participants in this study, fit neatly into four interacting domains: immediate electrical outcomes, procedural and technical performance, patient-related factors, and long-term clinical markers. Operators placed particular emphasis on acute QRS narrowing, stable low thresholds, high sensing amplitudes, and initial capture in the appropriate conduction fibres as intra-operative predictors. These were interpreted against a backdrop of patient suitability; with elderly, frail, or anatomically complex patients often benefitting disproportionately from the reproducibility and stability of LBBAP.

4.7 Result

The findings presented in this chapter bring together the experiential knowledge of electrophysiologists, cardiologists, specialist nurses, and device technicians to build a multi-layered understanding of how His Bundle Pacing (HBP) and Left Bundle Branch Area Pacing (LBBAP) perform in the setting of cardiac resynchronization therapy (CRT). Through a thematic lens, the study explored three intertwined objectives: differences in pacing performance, the safety and practicality of each technique, and the patient, procedural, and electrical indicators that signal the highest likelihood of sustained benefit.

Across all professional groups, there was marked agreement that both HBP and LBBAP can achieve physiologically favourable ventricular activation compared with conventional biventricular pacing. Acute electrical results in terms of QRS duration narrowing were described as significant for both modalities. However, in day-to-day practice, LBBAP was

more often associated with tighter and more reproducible synchrony. This consistency was valued not only as a technical achievement but as a foundation for long-term clinical improvement, with cardiologists in particular linking repeatable QRS narrowing to sustained gains in left ventricular ejection fraction and reduced symptom burden.

Electrical stability was a recurrent dividing line between the modalities. LBBAP was consistently reported to produce lower and more stable capture thresholds, often well under 1 V at the point of implantation and maintained over time. R-wave amplitudes were generally higher, which participants associated with reliable sensing and reduced device troubleshooting. HBP, while capable of delivering excellent synchrony in select cases, was more prone to threshold variability, occasional loss of selective His capture, and the need for lead revision. These observations mirror multicentre literature where threshold instability in HBP has been linked to revision rates, whereas LBBAP outcomes in large series demonstrate steady electrical parameters and rare instances of significant lead-related complications.

In terms of safety and procedural practicality, participants emphasised that while both techniques can be delivered successfully in the majority of appropriate patients, their learning curves and technical demands differ. Initial mastery of LBBAP was described as relatively swift; once key skills were in place, implant times shortened and reproducibility improved across diverse patient anatomies. For HBP, operators spoke of longer procedures, multiple mapping attempts, and greater susceptibility to anatomical obstacles, such as septal fibrosis or poor His signal, which in some cases restricted its applicability. Adverse events with LBBAP, such as septal irritation or perforation, were reported as infrequent and clinically less significant, with incidence decreasing as operator experience grew. In contrast, the principal longer-term safety concern for HBP centred on threshold rises, loss of capture, and system revisions, factors that can negate initial benefits and increase patient risk over time.

Patient selection emerged as an important influence on both choice of pacing modality and expected response. LBBAP was described as particularly advantageous for elderly or frail individuals, and for those with complex or previously unsuccessful CRT histories, due to its procedural efficiency and predictable electrical outcomes. HBP retained a role in anatomically favourable cases where engaging the proximal conduction system offered optimal physiological correction, but was less widely applicable in high-risk or technically complex contexts. In this way, anatomical feasibility, baseline conduction characteristics, and overall patient resilience were consistently intertwined with procedural outcomes in predicting benefit. Clinicians described a consistent approach for predicting which patients will respond best to CRT, based on a combination of procedural and patient factors they observe during

implantation. In both LBBAP and HBP, three main indicators led to strong confidence in a positive, long-lasting response; achieving clear and sustained narrowing of the paced QRS complex meaning the electrical impulse spreads quickly and normally through the heart; obtaining low and stable pacing thresholds at the end of the procedure, along with strong sensing signals from the lead; and selecting patients whose cardiac anatomy and clinical profile fit the chosen pacing method.

When these attributes were present; especially reproducible QRS narrowing and reliable electrical measurements; clinicians felt optimistic about a good outcome, whether using LBBAP or HBP. However, the findings also highlighted distinct differences between the two techniques in achieving these predictors. With LBBAP, operators found it easier to deliver immediate and consistent QRS narrowing, along with low, stable thresholds and high sensing amplitudes, even in elderly or anatomically complex patients. This gave them greater confidence in lasting benefit for a broader range of cases. In contrast, HBP could produce highly physiological QRS patterns in select patients with favourable anatomy, but was more often limited by higher or unstable thresholds and occasional loss of capture, making long-term response harder to guarantee.

Overall, the interview data showed that LBBAP more reliably met all three predictive criteria across diverse patient groups, resulting in more consistent clinical and electrical improvement. HBP, while powerful in the right context, was more susceptible to technical hurdles that could undermine these predictors, especially outside ideal anatomical scenarios. This real-world reasoning closely mirrors the objective markers of response described in the literature, reinforcing why LBBAP is increasingly seen as the preferred strategy for physiological CRT in routine clinical practice, with HBP reserved for selected cases where perfect conduction engagement is possible.

A notable point of convergence between participants and published data is the operational advantage of LBBAP. While HBP's theoretical appeal lies in its proximity to true physiologic activation, in real-world practice the reproducibility, procedural ease once learned, broader suitability across patient anatomies, and lower complication burdens of LBBAP position it as the more pragmatic choice for routine CRT delivery. Nonetheless, the responses also affirm that HBP should not be dismissed; in cases with a structurally and electrically accessible His-Purkinje system, it can offer results equal to or occasionally surpassing LBBAP. The challenge lies in its narrower applicability and greater technical fragility over time.

The study also highlights the important role of multidisciplinary perspectives in evaluating pacing modalities. Electrophysiologists brought detailed procedural and electrical insights;

cardiologists connected those technical outcomes with longitudinal functional and symptomatic improvements; nurses contributed an understanding of intraoperative workflow, safety safeguards, and early recovery; and technicians commented on follow-up predictability and the resource demands of ongoing device management. Together, these viewpoints build a more complete picture of what predicts CRT success in the real world. This collective lens also underlines that “response” is not defined by one parameter or timeframe, but by a continuum stretching from implantation through to stable, improved everyday function.

In summary, the chapter finds that while both conduction system pacing approaches can successfully deliver resynchronization, their performance profiles differ in ways that influence safety, applicability, and predictability of response. LBBAP holds a clear practical advantage in most patient groups due to its combination of reproducibility, electrical stability, and lower intervention burden over time. HBP, though more technically restrictive, remains an important option when conditions align. Across all settings, the combination of favourable acute electrical results, robust procedural metrics, and appropriate patient selection emerges as the surest path to a durable response. This reflects both the lived experience of clinicians and the evidence base in the literature, pointing towards a clinical trend in which LBBAP occupies the primary role in physiological CRT delivery, with HBP preserved for highly selected indications.

CHAPTER 5

5.1 Summary of Findings Based on Research Objectives

This research set out to explore several aspects of Cardiac Resynchronization Therapy (CRT) delivered through two modern conduction system pacing strategies: His Bundle Pacing (HBP) and Left Bundle Branch Area Pacing (LBBAP). The study's findings provide a comprehensive understanding based on expert viewpoints across electrophysiology, cardiology, and device management. The key conclusions are organized around the original research objectives, synthesizing the rich qualitative data collected.

5.1.1 Objective 1: Comparison of Pacing Performance

- Both HBP and LBBAP achieve physiological ventricular activation by directly stimulating the specialized conduction system, resulting in narrower QRS complexes compared to traditional biventricular pacing.
- However, LBBAP consistently produced narrower and more reproducible QRS durations, which translate clinically into more synchronous ventricular contractions and potentially better outcomes.
- Electrophysiologists reported that LBBAP demonstrated lower pacing thresholds than HBP, which remained stable over prolonged follow-up periods, indicating longer battery longevity.
- Sensing capabilities were also rated superior in LBBAP, with stronger and more reliable R-wave amplitudes recorded at the device, enhancing patient safety and device performance.
- HBP, while maintaining ideal physiological activation in select cases, was often challenged by higher and more variable thresholds, along with intermittent loss of capture, which could undermine long-term efficacy.
- Overall, clinicians expressed greater confidence in LBBAP's ability to deliver sustained electrical performance across a wider and more complex patient population.

5.1.2 Objective 2: Evaluation of Safety and Feasibility

- Procedural success rates were high for both approaches but differed in terms of technical challenge and reproducibility.
 - LBBAP was widely regarded as easier to learn and more consistently achievable, with operators noting a favourable learning curve that led to shorter procedure times and reduced fluoroscopy exposure over successive implants.

- LBBAP benefits from a broader and more accessible target area within the interventricular septum, making it more adaptable to variable cardiac anatomies.
- HBP implantation was recognized as technically demanding due to the small size and anatomical variability of the His bundle region. Operators frequently described prolonged procedure durations and the need for precise mapping and manipulation.
- Participants stated difficulties with lead dislodgement and threshold instability following HBP, contributing to higher rates of device revision or reprogramming.
- LBBAP appeared to have a slightly more favourable procedural safety profile, particularly in elderly or frail patients.
- Nurses and technical staff stated that LBBAP's procedural simplicity translated into smoother workflows, less frequent programming adjustments, and more predictable post-implant device behaviour compared to HBP.

5.1.3 Objective 3: Identification of Predictors of Response

- Key determinants of a favourable CRT response emerged at the intersection of patient selection, procedural factors, and immediate electrical outcomes.
- Clinicians emphasized a triad of predictors: consistently narrow QRS complexes achieved during implantation, low and stable pacing thresholds, and strong sensing amplitudes at lead placement.
- Patient factors such as preserved His-Purkinje conduction, less extensive fibrosis, younger age, and lower comorbidity burden influenced modality choice.
- Within this framework, LBBAP was favoured for patients with distal conduction system disease, septal fibrosis, or those considered fragile due to age or comorbidities.
- HBP's use was often limited to cases with intact proximal conduction, where electrical engagement of the native His bundle could be reliably achieved.
- Notably, the reproducibility of pacing results, especially the maintenance of narrow QRS morphology across follow-ups, was linked to sustained symptomatic and echocardiographic improvement.
- These response predictors align with objective measures from the literature, reinforcing their clinical validity.

5.2 Limitations

While the study provides valuable insights, there are several limitations. Firstly, the relatively small and purposive sample size limits the generalisability of findings beyond the study's

context. The participating clinicians are from few centres with established expertise in conduction system pacing, which may not reflect the broader clinical environment.

Secondly, the rapidly evolving nature of the field introduces additional complexity. As device technology, delivery tools, and operator experience progress rapidly, findings related to procedural ease and long-term outcomes may become outdated or may differ across newer iterations of hardware and techniques.

Lastly, potential biases due to qualitative methodology, including participant self-selection and subjective reporting, may influence the results. Practitioner perspectives, while rich and detailed, may be affected by personal experience, institutional preferences, and prior exposure to pacing modalities.

5.3 Recommendations

5.3.1 Clinical Recommendations

In light of the study's findings, several clinical recommendations emerge. Given its superior procedural reproducibility, lower and more stable pacing thresholds, and supportive safety profile, LBBAP should be considered the optimal conduction system pacing strategy for CRT candidates, especially those with complex disease, frailty, or prior device implants. Its adaptability to a wide range of patients and efficient implantation make it a practical choice for routine use.

However, HBP maintains an important role in scenarios where the patient's conduction system is intact, and the His bundle can be selectively engaged to ensure the most physiological ventricular activation possible. Clinicians should carefully assess patient anatomy and clinical status when selecting the pacing modality, recognizing that HBP may demand greater operator skill and carry risks of threshold increases over time.

Additionally, focused training is recommended to shorten the learning curve and ensure procedural safety and efficacy, particularly for operators adopting LBBAP. Dedicated protocols for device monitoring, threshold management, and early detection of complications should be incorporated into post-implant care pathways to enhance patient outcomes.

5.3.2 Academic Recommendations

From an academic and research perspective, further prospective studies with larger, diverse patient cohorts are necessary to quantify the comparative efficacy, safety, and durability of LBBAP and HBP. Long-term outcome research should extend follow-up periods to capture metrics such as heart failure hospitalization, mortality, and device longevity.

Investigations focusing on complex populations; such as patients with extensive fibrosis, congenital heart disease, or prior device therapy; would provide critical knowledge on the limits and adaptability of conduction system pacing strategies.

Future research should also include the impact of evolving device technologies and operator learning curves on clinical outcomes to inform best practices and training frameworks.

5.4 Conclusion

In summary, this research contributes a nuanced understanding of the evolving role of His Bundle Pacing and Left Bundle Branch Area Pacing in cardiac resynchronization therapy. The findings highlight the clear strengths of LBBAP in terms of procedural simplicity, electrical performance, and broader applicability to varied patient profiles. While HBP remains a valuable tool in select cases, its technical challenges and potential for less predictable outcomes limit its widespread adoption.

Through integrating multi-disciplinary professional perspectives, this study underscores the importance of considering patient-specific factors, procedural feasibility, and immediate electrical results in selecting pacing strategies. As conduction system pacing continues to evolve, leveraging the insights gained here will facilitate more personalized, effective, and safe CRT delivery.

Ultimately, this research lays groundwork for future quantitative validation and sustained innovation, striving toward the goal of optimising heart failure management through refined physiological pacing.

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APPENDIX A– THEMATIC ANALYSIS

Thematic Analysis of Electrophysiologist’s Interview

Theme 1: Factors Influencing Pacing Modality Selection

Definition: This theme captures electrophysiologists’ clinical and anatomical considerations when choosing between His Bundle Pacing and Left Bundle Branch Area Pacing for CRT patients.

Emergence: Mentioned frequently in the context of patient-specific factors, procedure feasibility, and clinical judgement.

Sub-themes:

- **1.1 Anatomical and Conduction System Status:** Preference for HBP if the His-Purkinje system is intact and conduction block is proximal; LBBAP favoured with fibrosis, poor His signal, or distal conduction disease.
- **1.2 Patient Health and Demographics:** LBBAP often chosen for elderly or frail patients due to safety and reproducibility.
- **1.3 Institutional & Technological Factors:** Workflow shifts toward upfront LBBAP screening; decisions also depend on equipment availability and operator expertise.
- **1.4 Procedural Predictors:** QRS morphology, extent of conduction disease, and previous lead implant history.

Quotes:

EP 1: If the HIS area is (0:57) fibrotic or thresholds are unacceptably high, left bundle branch area pacing is preferred due (1:03) to its higher implant success and more consistently low thresholds.

EP2: Our workflow has shifted to screening most CRT candidates for LBBAP upfront, (0:40) given the increasing evidence for stability and high active success rate..... There are also other factors affecting my decisions, such as (1:03) the institutional experience, the equipment availability and just patient specific features, (1:10) including variation in their anatomical structures and previously device history, if they had any.

EP 3: When there's evidence of distal conduction system disease, (0:54) failed or high-risk biventricular phasing or anatomic limitations, I'm more likely to choose (1:00) LBBAP.

EP 4: And in patients with previous failed CRT attempts, (0:48) dilated cardiomyopathy, or poor health signals, LBBAP is usually selected for its technical ease (0:55) and predictable capture characters.

Theme 2: Pacing Performance - Thresholds, Sensing, and Ventricular Activation

Definition: This theme focuses on clinician's observations regarding the electrical performance of HBP and LBBAP devices in CRT, including pacing thresholds, sensing amplitudes, and ventricular activation patterns.

Emergence: Evident in detailed comparative statements of device performance and patient ECG outcomes.

Sub-themes:

- **2.1 Stability and Magnitude of Thresholds:** LBBAP shows consistently low and stable pacing thresholds over time; HBP thresholds can rise and require higher outputs.
- **2.2 Sensing Amplitudes:** LBBAP provides higher and more reliable sensing amplitudes than HBP, which can have variable and reduced sensing signals.
- **2.3 Ventricular Activation & QRS Duration:** Both approaches narrow paced QRS compared to biventricular pacing, but LBBAP more often produces narrower and reproducible QRS complexes.

Quote:

EP1: See, like LBBAP consistently provides lower and (1:45) more stable pacing thresholds, often well below 1 volt at implant and maintained over follow-up (1:52) even at 12 months or beyond. So sensing amplitudes are also generally higher with LBBAP, (1:59) which is reassuring for lead stability and device longevity.

EP2: The QRS duration is comparable between HBP and LBBAP, but I have found LBBAP more reliable, (2:08) especially in difficult cases or in the case of scar tissues.

EP3: Sensing can be challenging, particularly if His signal is small or unstable. LBBAP produces (1:40) significantly higher R-wave amplitudes... Activation times are physiologic in both techniques, (1:53) but LBBAP more consistently reduces the QRS duration, potentially translating to better (1:59) ventricular synchrony.

EP4: (1:24) Over multiple years of practice, LBBAP has outperformed HBP in all pacing characters in my (1:32) CRT cohort. Lower and steadier pacing thresholds, high and sustained sensing amplitudes, and clear (1:39) and narrow QRS complexes have made it my preferred technique over time.

Theme 3: Technical Challenges and Procedural Experience

Definition: Electrophysiologists' descriptions of the practical difficulties and learning curves associated with implanting HBP and LBBAP leads.

Emergence: Frequent references to technical demands, mapping precision, procedural time, and complication avoidance.

Sub-themes:

- **3.1 HBP Technical Demands:** Requires meticulous mapping, has a narrow margin for error, and issues with lead stability and fibrosis complicate implantation.
- **3.2 LBBAP Procedural Reproducibility:** Viewed as more straightforward and consistent after initial training; still requires vigilance to avoid septal or left ventricular perforation.
- **3.3 Impact of Prior Devices and Anatomy:** Complex cases with prior leads or abnormal anatomy add challenges, especially for HBP.

Quotes:

EP1 : Implanting HBP leads can be technically demanding... LBBAP now has a higher overall success rate and faster procedure times.

EP1: With LBBAP, the procedures rapidly become more reproducible after initial training.

EP2 : In HBP, it tends to require repeated mapping and multiple lead delivery (2:35) attempts, particularly in the patients with prior CRT lead, so the complex anatomy, you know.

EP3 : LBBAP implantation is more straightforward and reliable, even in (2:34) patients with significant septal or myocardial disease.

EP4: Challenges, yeah, with HBP, the margin for error is extremely narrow, and lead displacement or (2:12) instability is a common challenge I faced, especially in the early post-implant period.

Theme 4: Complication Rates and Procedural Difficulties

Definition: Comparison of complication profiles, risks, and device-related follow-up interventions experienced with HBP and LBBAP.

Emergence: Discussed in terms of lead dislodgements, threshold rises, revisions, and procedural risks.

Sub-themes:

- **4.1 Lead Dislodgement and Loss of Capture:** HBP associated with higher frequencies of acute and chronic lead dislodgement and threshold increases.

- **4.2 LBBAP Safety Improvements:** Early concerns about septal perforation have lessened with experience; generally fewer lead revisions and device complications than HBP.
- **4.3 Device Alerts and Revisions:** More frequent device-related interventions required with HBP due to variable pacing capture and sensing.

Quotes:

EP1: HBP carries a higher risk of acute and chronic (3:49) lead dislodgement as well as a gradual increase in pacing thresholds. So it's necessitating (3:55) more frequent surveillance or even re-intervention.

EP1: LBBAP is not without risks. (4:03) The primary concern early on was the septal perforation, but this has become rare with (4:08) increasing experience. LBBAP has resulted in fewer lead revisions and less lead instability. (4:14) So overall, complication rates have been lower.

EP2: In specific to HBP, we have seen some cases of rising thresholds that mandated system revision, (3:41) especially in active or younger patients, you know. (3:45) The loss of his capture can be abrupt and concerning.

EP3: Device related complications, alert notifications, increased outputs or loss of (3:05) capture have been more frequent with HBP. LBBAP has delivered a more stable lead environment.

EP4: Lead performance issues, I would say, including high chronic output requirements, (2:55) intermittent capture, and dislodgement are much more common with HBP.

Theme 5: Long-Term Outcomes and Impact on Patient Care

Definition: Clinician's observations on sustained cardiac function improvements, symptom relief, hospitalization rates, and patient quality of life according to pacing modality.

Emergence: Recurring reports on functional benefits, device reliability, and patient well-being during follow-up.

Sub-themes:

- **5.1 Durable Device Function and Clinical Benefits:** Both HBP and LBBAP improve ejection fraction and symptoms, but LBBAP shows better long-term stability and fewer device alerts.
- **5.2 Patient Hospitalizations and Quality of Life:** Fewer heart failure hospitalizations and improved quality of life are noted more often in LBBAP patients.

- **5.3 Device Stability Confidence:** LBBAP associated with greater device stability, reducing patient and clinician anxiety regarding device failures.

Quotes:

EP1: It's like overall long-term follow-up, both HBP and LBBAP (4:41) have produced notable improvements in left ventricular ejection fraction and patient quality (4:47) of life compared to the traditional CRT non-responders.... However, the durability of response (4:53) and device function is superior with LBBAP as there are fewer device alerts, re-interventions, (5:00) or rises in pacing threshold. So many of my LBBAP patients remain symptomatically improved (5:07) with less frequent heart failure hospitalization.

EP2: Most of my patients in both groups show QRS narrowing and clinical benefit, (4:28) but those with LBBAP rarely require lead revision or reprogramming. (4:34) There is greater device stability and less anxiety about the device failure. (4:39) Ejection fraction improvements are also significant for both, (4:43) but sustained improvements are more likely with LBBAP due to its stable electrical parameters.

EP3: LBBAP's technical performance translates directly to durable (4:00) improvements in cardiac function and life quality.

EP4: For long-term outcomes, LBBAP recipients demonstrate both maintain systolic function (3:36) and durable electrical synchrony. Freedom from device-related complications is higher

Summary

This thematic analysis highlights that electrophysiologists weigh several clinical and technical factors in choosing between HBP and LBBAP, with a tendency to prefer LBBAP owing to better procedural ease, pacing stability, and long-term safety profiles. While HBP offers physiologic activation potential, its technical challenges and variable pacing thresholds limit its broader use. The clinical emphasis on patient-specific anatomy and comorbidities further guides modality selection. The findings align strongly with the research objectives, addressing pacing performance, safety and feasibility, patient predictors of response, long-term outcomes, and practical decision-making challenges.

Thematic Analysis of Cardiologist Interviews

Theme 1: Comparison of Clinical Effectiveness of HBP and LBBAP

Definition: Clinician's views on how HBP and LBBAP compare in improving patient symptoms, exercise tolerance, and cardiac function in CRT recipients.

Emergence: Frequent emphasis on physiological ventricular activation translating into clinical benefits, with opinions on consistency and sustainability.

Sub-themes:

- **1.1 Improvement in Symptoms and Exercise Capacity:** Both modalities improve heart failure symptoms and patient exercise tolerance over traditional CRT.
- **1.2 Durable Improvements in LVEF:** LBBAP often produces more reliable and long-lasting left ventricular ejection fraction improvements.
- **1.3 Stability of Ventricular Synchrony:** LBBAP provides tighter and more reproducible ventricular activation compared to HBP, which may be less stable due to pacing threshold variability.

Quotes:

Cardiologist 1: In my opinion, both HBP and LBBAP provide (0:46) physiological ventricular activation, which translates clinically into improved symptoms, (0:52) exercise tolerance and reduced heart failure severity comparing to the traditional (0:57) biventricular pacing.

Cardiologists 1: Heart rhythm stability is generally excellent with LBBAP (3:02) and LVEF improvements on echocardiography are maintained over longer periods.

Cardiologists 3: However, left bundle pacing's wider capture area and lower pacing (0:53) thresholds allow it to maintain tighter electrical synchrony in more patients, resulting in improved (0:59) and stable LVEF gains over months.

Cardiologists 2: LBBAP patients tend to experience more durable benefits likely because the (0:51) pacing thresholds remain low and ventricle activation times are shorter and more physiologic.

Theme 2: Clinical and Patient-Specific Factors Impacting Pacing Strategy

Definition: Key clinical considerations guiding the choice between HBP and LBBAP for individual CRT patients.

Emergence: Participant reflections on conduction disease patterns, QRS morphology,

anatomy, and patient frailty linked to pacing strategy decisions.

Sub-themes:

- **2.1 Electrical Conduction and Anatomical Status:** Patients with proximal His conduction block are candidates for HBP; distal conduction disease or complex anatomy favours LBBAP.
- **2.2 Procedural Feasibility and History:** Failed biventricular leads, limited vascular or venous access, and institutional equipment influence pacing modality choice.
- **2.3 Patient Health and Preferences:** Age, frailty, and patient willingness regarding procedure complexity and follow-up impact decisions.

Quotes:

Cardiologist 1: For example, patients with proximal His conduction (1:51) block but preserved distal conduction are candidates for HBP. And in contrast, patients (1:57) with the distal conduction system disease or complex anatomy benefit from LBBAP.

Cardiologist 1: So age, (2:04) frailty and venous access also influence the decision making as LBBAP often offers the greater (2:11) procedural success and safety in challenging cases.

Cardiologists 2: If the patient has prior failed ventricular leads or (1:29) limited vascular access, LBBAP is generally in favoured.

Theme 3: Post-Implant Follow-Up; ECG, Rhythm Stability, and Cardiac Function

Definition: Observations on differences in post-implant heart electrical patterns, rhythm stability, and echocardiographic findings between HBP and LBBAP recipients.

Emergence: Noted variations in QRS duration stability, rhythm reliability, and ventricular function.

Sub-themes:

- **3.1 QRS Duration and Consistency:** LBBAP maintains consistently narrower QRS complexes (<130 ms), whereas HBP may show intermittent loss of capture or conduction block.
- **3.2 Heart Rhythm Stability:** LBBAP exhibits more stable paced rhythms and fewer arrhythmic complications relative to HBP.
- **3.3 Echocardiographic Correlates:** Durable LVEF improvements observed with LBBAP; variable improvements and occasional arrhythmic episodes with HBP.

Quotes:

Cardiologists 1: LBBAP tends to achieve more pronounced and consistent QRS narrowing, (2:43) which often results in a QRS duration less than 130 milliseconds. So, the HBP also yields (2:49) narrow QRS patterns, but occasionally losses capture or demonstrates intermittent conduction (2:56) block on ECG during follow-up.

Cardiologists 2: So, the HBP also yields (2:49) narrow QRS patterns, but occasionally losses capture or demonstrates intermittent conduction (2:56) block on ECG during follow-up.

Cardiologists 3: Correspondingly, overall cardiac function and ventricular synchrony via (3:03) echocardiography remains stable or improve over time with left bundle pacing which can be (3:09) less consistent with his bundle pacing.

Theme 4: Long-Term Safety and Feasibility in Clinical Practice

Definition: Clinician perspectives on the procedural risks, safety profiles, and routine use feasibility of each pacing method.

Emergence: Discussions centred on procedural complexity, complication rates, follow-up needs, and operator expertise.

Sub-themes:

- **4.1 Procedural Simplicity and Reproducibility:** LBBAP is generally faster, has a wider implantation zone, and is easier to reproduce consistently; HBP is more technically demanding.
- **4.2 Device and Lead Complications:** LBBAP shows fewer lead-related problems and lower pacing thresholds, reducing battery drain and device replacements.
- **4.3 Follow-Up Burden:** HBP patients often require more frequent monitoring and sometimes lead revisions or reprogramming.

Quotes:

Cardiologist 1: LBBAP has demonstrated excellent long-term safety with fewer lead (3:21) related complications, such as the dislodgement or rising pacing thresholds. Procedure time tend (3:31) to be shorter and implants are more reproducible, which makes the LBBAP more feasible for routine (3:36) practice. And in case of HBP, which is remaining as safe, but can be technically demanding with (3:44) a higher risk of threshold increases and the need for lead revisions, which limits its widespread (3:50) adoption.

Cardiologist 2: LBBAP's (2:59) lower and more stable pacing threshold over time-reduced battery drain and device replacements, (3:04) which is advantageous

Cardiologist 3: Left bundle pacing appears more feasible due to (3:31) the wider implantation zone and relative procedural simplicity. Its safety profile is favourable. That is (3:39) major procedural complications are rare and long-term durability is strong.

Cardiologist 2: HBP's late stability standards and threshold rises (3:16) necessitate more frequent follow-up and sometimes three interventions affecting feasibility.

Theme 5: Patient Outcomes-Readmissions and Response

Definition: Variability in patient clinical stability, hospital readmission, and overall response to therapy with each pacing modality.

Emergence: Consistent reporting of fewer heart failure readmissions and more stable responses with LBBAP.

Sub-themes:

- **5.1 Reduced Heart Failure Hospitalizations:** LBBAP recipients generally have lower rates of rehospitalizations and device-related complications.
- **5.2 Sustained Clinical Stability:** LBBAP patients show more durable symptomatic improvements and stable cardiac function.
- **5.3 Need for Intensive Monitoring:** HBP patients sometimes require closer surveillance due to pacing variability and threshold fluctuations.

Quotes:

Cardiologist 1: Actually, yes, patients with LBBAP generally (4:04) demonstrate lower rates of heart failure hospitalizations and the re-hospitalizations (4:10) for device-related issues. This is likely due to more stable pacing parameters and consistent (4:16) ventricular resynchronization. And HBP patients may have slightly higher readmission rates related (4:22) to the threshold rise or maybe due to the loss of capture, which may require the device reprogramming (4:29) or lead revision.

Cardiologist 2: In my practice, LBBAP recipients experience fewer hospital readmissions later to heart (3:38) failure. Stable electrical parameters and better device longevity may drive this trend. (3:43) HBP patients also benefit but require more intensive monitoring, and some have

experience (3:48) readmission due to intermittent capsule failure or related complications. (3:53)

Cardiologist 3: LBBAP patients have better overall clinical stability and fewer (4:28) hospital readmissions in medium and long-term follow-up. This is reflected in improved survival (4:35) trends and fewer device interventions.

Summary

The cardiologists' insights broadly support the view that while both HBP and LBBAP improve cardiac function and symptoms in CRT patients, LBBAP tends to offer more consistent, durable benefits with fewer complications and procedural challenges. Clinical decision-making incorporates patient conduction status, anatomical considerations, and practical issues like prior device history and procedural feasibility. Moreover, follow-up data suggest that LBBAP delivers more stable ventricular activation and lower rehospitalization rates. These findings directly address the research objectives of pacing performance, safety and feasibility, predictors of response, patient outcomes, and clinical decision processes.

Thematic Analysis of Cardiac Rhythm Management Technicians Interviews

Theme 1: Programming Complexity and Troubleshooting Demands

Definition: Differences in setup, optimization, and early troubleshooting between HBP and LBBAP from a technical programming perspective.

Emergence: Repeated references to precision needs, polarity adjustments, capture confirmation, and time required for optimization.

Sub-theme

- **1.1 Precision and Time Intensity with HBP:** HBP requires meticulous programming due to small target zone, variable thresholds, and need for selective capture.
- **1.2 Streamlined Setup with LBBAP :** LBBAP typically allows quicker confirmation of capture and interval optimization, with fewer early adjustments.

Quotes:

Technician 1: The HIS bundle is such a small target, so (0:51) we often see variable thresholds and need more time optimizing output and sensing values.

Technician 2: The differences is that I find (0:45) HBP require more programming finesse. (0:48) Sometime we have to adjust polarity (0:51) to avoid far field signal or ensure selective capture

Technician 1: So (0:58) to ensure a reliable capture, left bundle pacing is technically more forgiving and the target (1:05) area is larger and also the thresholds are very stable early on. So programming is often quicker (1:12) and follow-up adjustments is less frequent.

Technician 2: With LBBAP, we are usually able to confirm capture and optimize intervals faster.

Theme 2: Sensing and Threshold Profiles

Definition: Comparative observations on sensing amplitudes and pacing threshold behaviours over time.

Emergence: Consistent technician commentary on LBBAP's stronger signals and stable thresholds versus HBP's variability.

Sub-theme

- **2.1 Superior Sensing with LBBAP:** LBBAP provides higher R-wave amplitudes and clearer electrograms, aiding reliable sensing and programming confidence.
- **2.2: Threshold Variability and Drift in HBP:** HBP more often shows higher initial thresholds, fluctuation, and drift that necessitate higher outputs and frequent monitoring.

Quotes:

Technician 1: ...left bundle pacing, nearly always delivers higher R-wave amplitudes.

Technician 3: LBBAP programming tends to be more straightforward with better R wave sensing (0:56) and less ambiguity.

Technician 1: His bundle pacing (1:30) in contrast can have lower sensing values and more fluctuation over time. Pacing thresholds (1:38) with his bundle pacing tend to be higher and sometimes drift requiring more frequent monitoring.

Technician 2: HBP threshold may arise (1:36) and that means we sometimes keep output higher (1:40) to guarantee capture which isn't as efficient (1:43) for battery longevity.

Theme 3: Safety Protocols and Performance Assurance

Definition: Protocolized checks, communication workflows, and patient education practices to ensure safe device function.

Emergence: Clear descriptions of verification routines, cross-team coordination, and patient guidance.

Sub-theme

- **3.1 Standardized Verification and Safety Margins:** Routine multiple output capture checks, threshold testing, oversensing assessment, and programmed safety margins especially for HBP.

- **3.2 Interdisciplinary Communication and Patient Education:** Continuous data review, clear communication of alerts and trends to clinical teams, and instructing patients about symptoms and remote alerts.

Quotes:

Technician 1: Verify sensing and capture at multiple outputs, (2:02) so check for loss of capture with threshold testing and always assess for oversensing or (2:09) inappropriate pacing.

Technician 3: We routinely program safety (1:34) margins above the threshold for HBP and regularly test in multiple positions.

Technician 2: I make sure diagnostic data are thoroughly reviewed, (2:01) looking for any drop in the impedance or threshold (2:04) or evidence of signal noise. (2:07) And also I educate patients about when to report symptoms

Technician 1: I'm responsible for programming the remote monitoring parameters and also reviewing (3:07) transmissions of for any shifts in thresholds or sensing. For his bundle pacing, I flag any trend (3:14) upward in threshold quickly, as it can mean partial loss of capture.

Theme 4: Modality-Specific Complications and Maintenance

Definition: Patterns of device-related issues and the differential maintenance burden between HBP and LBBAP.

How it emerged: Frequent contrasting of HBP risks (loss of capture, battery drain) with LBBAP's lower intervention rates post-implant.

Sub-theme

- **4.1 HBP linked issues-capture loss, rising thresholds, battery drain:** HBP more often requires lead repositioning, higher programmed outputs, and closer follow-up due to unstable thresholds and far-field sensing.
- **4.2 LBBAP stability with rare implant risks:** LBBAP seldom requires reintervention after stable implant; rare issues relate to septal perforation recognized and addressed intraoperatively.

Quotes:

Technician 1: With his bundle pacing, loss of capture and (2:34) the threshold changes are the main concerns. I have seen a few cases needing lead reposition.

Technician 2:the battery trend can be faster with HBP (2:32) if you have to program high outputs. (2:35) The far field sensing or inappropriate pacing (2:39) are also more challenging in HBP. (2:43) Then the LBBAP patients on the other hand (2:47) hardly ever need re-interventions.

Technician 1: Left bundle pacing rarely has those issues after the implant. So the complications are uncommon, (2:47) if the initial reposition is correct.

Technician 3: “LBBAP’s rare issues are more related to septal perforation at implant... usually seen and fixed up front.”

Theme 5: Follow-Up Strategy and Remote Monitoring

Definition: Operational differences in monitoring cadence, alert management, and response prioritization by modality.

Emergence: Consistent reports of more intensive early follow-up for HBP and smoother remote monitoring sufficiency for LBBAP.

Sub-theme

- **5.1 Intensified Surveillance for HBP:** Earlier and more frequent in-person checks, proactive response to threshold rises, and higher urgency for HBP related alerts.
- **5.2 Remote Monitoring Sufficiency for LBBAP:** LBBAP typically managed effectively via remote checks unless parameters change, reflecting stable device behaviour.

Quotes:

Technician 2: I schedule early follow-up visit for HBP, (3:05) but for LBBAP, remote checks are often enough (3:09) unless something changes.

Technician 1: For his bundle pacing, I flag any trend (3:14) upward in threshold quickly, as it can mean partial loss of capture.

Technician 3: I always review (2:38) alert in details, responding fastest to HBP alerts.

Technician 3: For LBB pacing, less adjustment is usually needed, but we still keep a close eye on any (1:47) unexpected parameter changes.

Summary

Technician’s report that programming and troubleshooting His Bundle Pacing (HBP) require greater precision and time due to smaller lead targets and variable pacing thresholds, whereas Left Bundle Branch Area Pacing (LBBAP) offers more stable thresholds and simpler programming. LBBAP consistently demonstrates higher sensing amplitudes and lower, more stable pacing thresholds compared to HBP, which often shows threshold fluctuations and requires more frequent monitoring. Safety protocols emphasize rigorous testing and cross-team communication, especially for HBP leads. Device-related complications such as capture loss, threshold rises, and battery drain are more common with HBP, while LBBAP complications are rare and mostly limited to initial implant issues. Follow-up care involves more intensive

early monitoring for HBP, while LBBAP patients are generally managed effectively through remote monitoring, reflecting the differences in device stability and maintenance needs.

Thematic Analysis of EP Lab Nurse Interviews

Theme 1: Early Patient Responses and Rhythm Stability

Definition: Nurses observations of immediate electrical stability and lead alarm frequency following HBP and LBBAP implantation.

Emergence: Consistent remarks about differences in pacing threshold fluctuations, alarms, and initial rhythm stability tied to device type.

Sub-themes

- **1.1 Pacing Threshold Fluctuations and Alarms (HBP):** HBP patients experience frequent threshold variability and lead alarms post-implant, sometimes necessitating reprogramming or clinical intervention.
- **1.2 Rhythm Stability and Lead Performance (LBBAP):** LBBAP generally results in stable early electrical parameters and fewer alarms or rhythm disturbances, easing immediate postoperative care.

Quotes:

Lab Nurse 1: We observe that the patients with his bundle pacing (0:39) sometimes have more frequent pacing threshold fluctuation immediately post-implant and which (0:46) can trigger lead alarms or require device reprogramming in the EP labs.

Lab Nurse 2: HBP patients occasionally present with intermittent capture (0:45) or threshold variability right after implantation, which can be challenging to manage.

Lab Nurse 2: With LBBAP, early rhythm stability is generally good and alarms related to (1:04) lead function or sensing are less common, making the immediate post-op period smoother.

Theme 2: Technical Challenges in Lead Placement and Troubleshooting

Definition: Intraoperative nursing experiences involving the complexity, testing, and adjustment requirements for each pacing method.

Emergence: Longer duration and greater complexity of HBP procedures contrasted with the more straightforward nature of LBBAP.

Sub-themes

- **2.1 Complexity and Time-Intensity (HBP):** HBP lead placement is technically demanding and often requires repeated lead testing and troubleshooting, with higher potential for instability and repositioning.

- **2.2 Procedure Efficiency and Stability (LBBAP):** Once placed, LBBAP leads tend to be stable; testing phase is shorter, and troubleshooting is seldom needed.

Quotes:

Lab Nurse 1: The main challenges are HBP lead placement is more (1:28) technically demanding, so we often spend longer time assisting with fine adjustment and testing. (1:36) His bundle area is small, making lead fixation delicate and sometimes unstable, which (1:42) results in frequent threshold testing during the procedure.

Lab Nurse 2: With LBBAP, (1:39) once the lead is placed deep into the left septum, the testing phase tends to be shorter (1:46) and the troubleshooting is infrequent because the lead fixation is generally more stable.

Theme 3: Key Intraoperative Nursing Care and Complication Management

Definition: Essential nursing care practices and preparatory steps required during pacing procedures, tailored to the modality.

Emergence: Careful preparation, tool management, and intraoperative vigilance for complications feature prominently.

Sub-themes

- **3.1 Preparation and Instrument Readiness (HBP):**
Meticulous preparation for longer procedures and potential lead repositioning is vital; sterility and readiness of multiple instruments are emphasized.
- **3.2 Complication Prevention and Equipment Handling (LBBAP):** Vigilant management of lead delivery sheaths and fluoroscopy equipment is key, with awareness of potential acute events like septal injury.
- **3.3 Documentation and Handover:** Thorough intraoperative data capture and effective verbal relay to the multidisciplinary team are crucial for continuity of care.

Quotes:

Lab Nurse 1: We prepare for multiple lead tests and potential repositioning, ensuring the (2:23) electrophysiologist has all necessary tools immediately available.

Lab Nurse 2: We emphasize careful management of (2:10) fluoroscopy equipment and lead delivery sheaths to prevent septal injury.

Lab Nurse 1: We provide a detailed handover including lead placement (3:23) success, pacing thresholds, sensing parameters, any intraoperative complications and alarm (3:30) occurrence.

Summary

EP lab nurses identify marked differences between HBP and LBBAP procedures with respect to early patient electrical stability and intraoperative technical complexity. HBP is linked to more threshold fluctuations, frequent alarms, and challenging lead placement, while LBBAP offers more immediate stability and less troubleshooting. Nurses play a critical role in preparation, complication management, and cross-team communication, ensuring safe patient outcomes irrespective of the pacing method.

Thematic Analysis of CCU Nurse Interviews

Theme 1: Immediate and Short-Term Post-Implantation Nursing Care

Definition: Nursing priorities, monitoring practices, and interventions directly following HBP or LBBAP device implantation in CRT patients.

Emergence: Both nurses repeatedly emphasized post-procedural vigilance, with distinctions based on pacing modality.

Sub-themes

- **1.2 Monitoring for Arrhythmias and Lead Dislodgement:** Careful ECG monitoring and instruction regarding gentle movement are prioritized, especially for HBP due to greater risk of lead displacement.
- **1.2 Wound Care, Infection, and Pain Management:** Emphasis on ensuring proper wound healing, minimizing hematoma, and managing pain for both groups. Education about the device is also a focus.

Quotes:

CCU Nurse 1: We check (0:42) ECGs frequently and stress gentle movement instructions as his bundle leads can shift (0:49) if patients aren't careful.

CCU Nurse 2: I always keep an eye on wound healing, risk of hematoma, and early signs of infection for (0:43) both groups.

Theme 2: Complications and Recovery Patterns by Pacing Modality

Definition: Observed differences in early complications, recovery speed, and post-op challenges between HBP and LBBAP.

Emergence: Nurses note that HBP is associated with more acute device-related issues and uncertainty post-surgery than LBBAP.

Sub-themes

- **2.1 Early Lead or Device related Challenges:** HBP linked to more frequent lead issues (loss of capture, threshold increases) than LBBAP, which is seen as smoother in early recovery.
- **2.2 Stability and Patient Confidence in LBBAP:** LBBAP recipients generally experience fewer challenges, and their stable device performance leads to more confident recovery.

Quotes:

CCU Nurse 1: With HBP, I have seen more lead (1:05) issues early, sometimes loss of capture, or increases in threshold. LBBAP patients usually (1:11) have fewer acute device related challenges, and early post-op checks are smoother.

CCU Nurse 2: There's less of that with LBBAP, meaning their recovery can be a bit quicker (1:27) and they may be able to mobilize sooner.

Theme 3: Patient Adjustment and Psychological Response

Definition: Nurse's assessments of patient adaptation, anxiety, and confidence post-discharge, as influenced by pacing method.

Emergence: Repeated comments on patient reactions and normalization of activities in the first weeks following CRT.

Sub-themes

- **3.1 Anxiety and Device Adjustment (HBP):** *HBP patients sometimes exhibit greater anxiety and need more reassurance and rechecks shortly after discharge.*
- **3.2 Confidence and Activity Resumption (LBBAP):** *LBBAP patients typically regain confidence and adjust more quickly, facilitated by stable pacing and effective education.*

Quotes:

CCU Nurse 1: The only difference (1:58) is that HBP patients sometimes seems a bit more worried about the device right after discharge, (2:06) especially if we had to do early rechecks.

CCU Nurse 1: I have had LBBAP patients tell me that (2:26) felt more energetic and had fewer palpitation.

CCU Nurse 2: I think LBBAP patients are usually more confident after the first follow-up, (2:13) probably because the pacing is stable.

Summary

CCU nurses highlight distinct nursing priorities and patient experiences depending on pacing modality. HBP requires heightened vigilance for lead issues and tends to prompt more patient anxiety and follow-up intervention. LBBAP shows more stable post-op performance, smoother recovery, and greater patient confidence. These themes address immediate care requirements and complication management; all central to the research objectives on safety, performance, and patient-centred outcomes.

APPENDIX B- ETHICS FORM



Ethics Application & Declaration Form

DISSERTATION TITLE: Comparing His Bundle Branch and Left Bundle Branch Area Pacing in Cardiac Resynchronization Therapy: Safety, Feasibility, and Predictors of Response.

RESEARCHER'S NAME: Joel Joseph Joseph

PROGRAMME OF STUDY: MSMDT


SUPERVISOR'S NAME: Patricia Mooney

DECLARATION:

The information in this application form is accurate to the best of my knowledge. I undertake to abide by the principles outlined by Innopharma/Griffith College ethics policy in my research dissertation. I confirm that I have completed a full ethics assessment for my research dissertation as per the college guidelines. I will not begin my primary research until such approval from my supervisor and/or ethics Committee has been obtained.

I pledge to carry out my research according to the Innopharma/Griffith College academic integrity standards. Any results presented in my dissertation will be from my own, original research, I will reference and/or acknowledge any material or sources used in its preparation and I will not plagiarise the work of anyone else.

For Student:

STUDENT SIGNATURE: 


DATE: 07/07/2025

The research contained within this research dissertation proposal has been approved.

For Supervisor:

Ethics Committee Approval Required:

Yes No

SUPERVISOR SIGNATURE: 

DATE: 07 Jul 2025

For Ethics Committee (if required):

Ethics Committee Approval Given:

Yes No

ETHICS COMMITTEE MEMBER SIGNATURE:

DATE:

NOTE: Supervisors are responsible for ensuring their students fill in this form correctly and that all ethical areas have been considered.

SECTION 1: DESCRIPTION OF RESEARCH STUDY

1.1 Purpose and objectives of research [300 words maximum/ use literature review findings to guide]

Cardiac Resynchronization Therapy (CRT) is an established treatment for managing heart failure in patients with conduction abnormalities. While biventricular pacing is the conventional approach, emerging methods like His Bundle Pacing (HBP) and Left Bundle Branch Area Pacing (LBBAP) are designed to restore more natural electrical conduction. This study aims to compare clinician perspectives on HBP and LBBAP, with a focus on their perceived safety, feasibility, and clinical effectiveness, to determine whether LBBAP is indeed viewed as a superior pacing strategy in CRT.

- Investigate clinician perspectives on pacing performance in CRT systems by gathering insights and experiences related to pacing thresholds, sensing effectiveness, and ventricular activation patterns with HBP and LBBAP.
- Determine Safety and Feasibility: Assess the procedural success, complications, and long-term safety of CRT.
- Identify Predictors of Response: Analyse patient-specific factors that predict a favourable response to each pacing strategy.

1.2 Research methodology: [300 words maximum/ detail how you will acquire your primary data (focus groups/interviews/online surveys etc). Proposed questions for questionnaires and/or interviews must be included in the appendix.

This study adopts a qualitative exploratory design, utilizing semi-structured interviews to collect primary data from clinical experts involved in Cardiac Resynchronization Therapy (CRT). The qualitative approach is chosen to capture in-depth, perspectives on the effectiveness, safety, and feasibility of His Bundle Pacing (HBP) and Left Bundle Branch Area Pacing (LBBAP).

Data Collection:

Interviews will be conducted individually via Zoom, providing a flexible and accessible platform for participants. Each interview will last approximately 30–45 minutes. A semi-structured interview guide will ensure consistency across sessions while allowing participants to elaborate on their experiences and insights. The guide covers key areas including pacing performance (thresholds, sensing, and activation patterns), safety and feasibility (procedural success, complications, device performance), predictors of patient response, long-term outcomes, and practical challenges in clinical decision-making.

Interview Structure:

The interviews will begin with an introduction to the study and consent procedures, followed by open-ended questions based on the interview guide. Probing questions will be used to explore emerging topics in greater depth. This structure ensures both coverage of essential topics and the flexibility to capture unanticipated insights.

Data Handling:

All interviews will be audio-recorded with participant consent to ensure accuracy. Recordings will be securely stored on authorised Griffith college drive, with controlled access. Transcripts will be anonymized, with all personal identifiers removed to maintain participant confidentiality. Data will be analysed using thematic analysis, allowing for the identification and interpretation of key themes relevant to the research objectives. This methodology enables the collection of rich, detailed data while upholding ethical standards and ensuring participant privacy. The findings will provide valuable insights into the clinical application and comparative effectiveness of HBP and LBBAP in CRT.

SECTION 2: POSSIBLE ETHICAL ISSUES

Answer 'yes' or 'no' to the following questions.

SUBJECT MATTER

Does the research proposal involve:

Research into specific company activities that would be deemed sensitive or confidential	No
Research into politically and/or racially/ethnically and/or commercially sensitive areas	No
Sensitive, personal, professional or corporate issues	No

RESEARCH PROCEDURES

Does the research proposal involve:

Research that might damage the reputation of companies or participants	No
Research that may negatively affect the reputation of Griffith College/Innopharma	No
Use of personal records without consent	No
Use of company data without consent	No
The offer of any inducements to participate	No
Audio or visual recording without consent	No
Using a language other than English	No

PARTICIPANTS

Does the research proposal involve:

People who are not competent and/or fluent in English	No
Does your research group include any of the following vulnerable groups	No

(Adults with psychological impairments; Adults with learning difficulties; Adults under the protection/control /influence of others (e.g. in care/prison); Relatives of ill people (e.g. parents of sick children); Hospital or GP participants recruited in a medical facility; persons under the age of 18)

If you have answered NO to ALL questions, please go straight to Section 4.

If you have answered YES to ANY question in SECTION 2, you must fill in SECTION 3.

SECTION 3: STEPS TAKEN TO AVOID ETHICAL ISSUES

[Only fill in this section if you answered YES to ANY of the questions in Section 3. For example, if you answered yes to including participants who are not fluent in English, you might put forward a plan that offers your survey in two languages to take this into account. Another example could be a study where the researcher wants to include information about the care received by children with a long-term condition but it would not be ethical to approach the children directly but it might be acceptable to instead ask parents questions about their child's care. If these plans are acceptable to your supervisor, you may not need to apply for ethical approval from the Ethics Committee].

- 3.1. If your ethics relates to **Subject Matter**, outline your action plan to work around any sensitive issues.
- 3.2. If your ethics relates to **Research Procedures**, outline your action plan to deal with possible ethical issues in your research procedures.
- 3.3. If your ethics relates to **Participants**, outline how you will protect vulnerable persons or those that do not have English as their first language.

Participants will be professionals previously known to the researcher through prior professional contact. They will be contacted directly by the researcher, and not through the medical facility. While some participants may currently be employed at the same facility, they are participating in this research in a personal capacity and not as representatives of the institution. All data will be anonymised, and there are no known or expected conflicts of interest between the researcher, the participants, or the medical facility. The purpose of the research and the voluntary nature of involvement will be clearly outlined in the Participant Information Letter and understanding of this will be confirmed through the Informed Consent.

SECTION 4: ABOUT YOUR PARTICIPANTS

- 4.1. Outline your participant profile and why you have chosen them for this study *[Do not provide names except where it is deemed impossible to conceal identity]*.
Electrophysiologists (EPs), Cardiologists, Cardiac care nurses (from CCU or EP labs),
Technicians specializing in cardiac rhythm management

Electrophysiologists:

As the primary specialists responsible for implanting CRT devices, electrophysiologists offer essential knowledge about the technical aspects, procedural challenges, and success rates of both pacing methods.

Cardiologists:

Cardiologists play a key role in selecting suitable patients for CRT and managing their ongoing care. Their clinical experience allows them to assess long-term outcomes and compare how patients respond to HBP and LBBAP over time.

Cardiac Nurses (working in CCU or EP labs):

These nurses are heavily involved in patient care before, during, and after device implantation. Their observations provide valuable insight into immediate post-procedure outcomes, patient comfort, and the practical challenges seen on the ward.

Cardiac Device Technicians:

These professionals are responsible for monitoring and maintaining pacing devices during follow-up appointments. Their input is important for understanding device function, long-term performance, and any technical issues encountered in everyday clinical practice.

The geographical scope of this study is limited to India. Participants will be selected from hospitals and cardiac centres where Cardiac Resynchronization Therapy (CRT) using His Bundle Pacing (HBP) and Left Bundle Branch Area Pacing (LBBAP) is routinely performed. All participants must have at least one year of hands-on clinical experience with both HBP and LBBAP techniques. This ensures that their insights are based on meaningful exposure and practical understanding of each method.

4.2 How do you plan to gain access to/contact/approach your participant(s).

Personal contacts and Ex Colleagues

SECTION 5: INFORMATION, CONSENT AND CONFIDENTIALITY

5.1 Participant Information Letter (PIL) for participants

[You must submit an information letter for participants with this application, as part of your appendices document. For online surveys, it is sufficient to include a paragraph summarising and explaining the purpose of the research at the beginning of the survey. In all other research e.g. interviews, phonecalls, a PIL should be provided to each participant before they are asked for their consent to take part. A template PIL is available in Moodle].

Please confirm below that your information letter covers:

Description of the research topic and method	Yes
Details of what participation will involve	Yes
Rights to anonymity	Yes
Confidentiality	Yes
Rights to withdraw from the research	Yes
The contact details of the researcher and supervisor (if necessary)	Yes

5.2 Informed Consent Form (ICF) for participants

[Informed consent is required for most research. For online surveys, it is sufficient to get the participant to tick two boxes at the beginning of the survey – one to state they understand the research and one to give consent. In all other research e.g. interviews, phonecalls, a signed consent form is required. If the data is gathered online e.g. zoom, a signed consent form can be scanned and sent to the researcher. A template ICF is available in Moodle. The signed ICFs, along with the surveys, audio files or interview notes etc. must be stored in the primary data folder on moodle and can be accessed by Innopharma staff for the purposes of verifying the authenticity of the research carried out and the data collected].

Please indicate below if your research requires a signed consent form by selecting the relevant option only:

Yes: my research requires signed consent and I have attached an ICF in the appendices of my application.

No: my research study involves an online survey only and/or does not require signed consent

SECTION 6: STORAGE OF DATA

[Please ensure that you are abiding by GDPR and the national Data protection laws <https://www.hrb.ie/funding/gdpr-guidance-for-researchers/gdpr-and-health-research/>].

The student is responsible for storage of data and this will be handed over to the college in an electronic format as part of the thesis submission i.e. primary data and completed ICFs where applicable will be added to the primary data folder on moodle. The rationale is to keep data as long as it is still useful and there is an intention to use it further for research so if this is not the case then this can be stipulated here and a shorter retention period given.]

6.1. How will you store the research data and for how long? How will you manage data protection issues?

Consent forms, transcripts and primary data will be securely stored on Griffith College's authorized OneDrive, with controlled access. The information will be retained from September 2024 to September 2025 and then permanently deleted to protect privacy. After the research is completed, all primary data, transcript and signed consent forms will be submitted digitally to the university as part of the thesis and transferred to the main data folder on Moodle. The study will comply with GDPR and national data protection laws, including obtaining clear participant consent. Participants will be fully informed about the study's purpose, their involvement, and data use. All personal identifiers will be removed from transcripts, and participant roles will be coded in the results to ensure anonymity. Non-anonymized data, such as signed consent forms and audio recordings, will be stored in a locked cabinet and on a secure server.

SECTION 7: NON-DISCLOSURE AGREEMENT & STUDENT CONSENT

7.1 Non-Disclosure Agreement (NDA)

Will the final dissertation contain any information pertaining to any source what would warrant the use of a Non-Disclosure Agreement (NDA) e.g. industry-based research?

No

7.2 Student consent

If a Non-Disclosure Agreement (NDA) is not required, does the Student consent to allow their completed dissertation to be held/published by Innopharma/Griffith College?

Yes

SECTION 8: RECORDING AND RETENTION OF DISSERTATION VIVA

8.1 Viva Recording

The Dissertation viva will be recorded. This recording may be used to facilitate assessment by Innopharma staff, a third reader if necessary and/or if requested by the external examiner for the Programme. The recording will be held in line with current GDPR guidelines and will not be made publicly available.

SECTION 9: DOCUMENT CHECKLIST

NOTE: Applicants must attach the following documents in electronic format to the appendix.

Which documents are added to the appendix? Please tick N/A if not applicable:

9.1 Participant Information Letter (PIL) for participant

Yes

9.2 Informed Consent Form (ICF) for participant	Yes
9.3 Questions/survey for interviewees/focus groups etc (can be in draft form)	Yes
9.4 Any other documents e.g. Non-Disclosure Agreement	N/A

I confirm that this application is complete and all required documents are included in the appendix.

For Student:
 STUDENT SIGNATURE: 
 DATE: 07/07/2025

SECTION 10: APPENDIX

Electrophysiologists (EPs)

1. What factors influence your choice between HBP and LBBAP for individual patients requiring CRT?
2. In your experience, how do pacing thresholds, sensing effectiveness, and ventricular activation compare between His Bundle Pacing (HBP) and Left Bundle Branch Area Pacing (LBBAP) in CRT patients?
3. Can you describe your experience with implanting HBP and LBBAP leads in CRT patients? What technical challenges have you encountered with each approach?
4. In your clinical practice, what have you observed regarding complication rates or procedural difficulties unique to HBP versus LBBAP?
5. Based on your follow-up with patients, how do long-term outcomes (e.g., device function, heart failure symptoms, quality of life) differ between those receiving HBP and those with LBBAP?

Cardiologists

1. From your perspective, how do HBP and LBBAP compare in terms of improving patient symptoms and cardiac function in CRT recipients?
2. What clinical or patient-specific factors do you consider most important when deciding on a pacing strategy for CRT?
3. When following up with patients who have received His Bundle Pacing (HBP) or Left Bundle Branch Area Pacing (LBBAP) as part of CRT, have you observed any differences in their ECG patterns, heart rhythm stability, or overall cardiac function?
4. What are your views on the long-term safety and feasibility of HBP versus LBBAP in routine clinical practice?
5. Have you noticed any differences in patient response or hospital readmission rates between HBP and LBBAP?

Nurses - EP Lab (Objective 1)

1. Have you noticed any differences in early patient responses, such as heart rhythm stability or lead alarms, associated with either pacing method during or immediately after implantation?

2. What challenges have you encountered in lead placement, testing, or troubleshooting with HBP compared to LBBAP?
3. What are the key considerations for intraoperative nursing care when assisting with HBP versus LBBAP procedures?
4. How do you monitor for and respond to acute complications or device-related issues in the EP lab setting?
5. How do you communicate procedural findings and immediate concerns to the broader cardiac care team following CRT implantation?

Nurses – CCU (Objectives 2/3)

1. What key nursing care considerations are involved in the immediate and short-term post-implantation period for patients receiving HBP or LBBAP?
2. Have you observed any differences in complication rates, recovery time, or post-op care challenges between the two pacing methods?
3. How do you contribute to early detection and reporting of complications or lead-related issues during routine monitoring?
4. In your experience, how do patients adjust over time to living with either HBP or LBBAP systems?
5. Have you noticed differences in patient-reported outcomes, such as symptom relief or confidence in the device, between the two groups?

Cardiac Rhythm Management Technicians

1. What technical differences do you encounter when programming and troubleshooting HBP versus LBBAP systems?
2. How do sensing amplitudes and pacing thresholds compare between HBP and LBBAP in your experience?
3. How do you ensure optimal device performance and patient safety when managing these advanced pacing systems?
4. Can you describe any device-related complications or maintenance issues that are more common with one pacing modality over the other?
5. What role do you play in follow-up and remote monitoring of CRT patients with HBP or LBBAP?