HUE UNIVERSITY
UNIVERSITY OF MEDICINE AND PHARMACY

KIEU NGOC DUNG

OPTIMIZATION OF ATRIOVENTRICULAR CONDUCTION INTERVAL USING ECHOCARDIOGRAPHIC DOPPLER AND CARDIAC CATHETERIZATION IN PATIENTS WITH ATRIOVENTRICULAR BLOCK UNDERGOING HIS-BUNDLE PACING

DOCTORAL DISSERTATION IN MEDICINE

Specialization: ***Internal Medicine***

Code: ***97 20 1 07***

HUE - 2025

This work was completed at:
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The dissertation will be defended before the Hue University Doctoral Dissertation Evaluation Committee.

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INTRODUCTION

1. Rationale and Significance of the Study

Current estimates suggest that approximately one million pacemaker implantations are performed worldwide each year, underscoring that pacemaker therapy and pacing management have become essential components of modern cardiovascular care. However, multiple studies have demonstrated that after 2 to 4 years of follow-up, 10–20% of patients with a right ventricular pacing burden exceeding 20% develop pacing-induced cardiomyopathy, which leads to impaired cardiac function, reduced ejection fraction, increased hospitalizations, and higher mortality. Since 2018, the European Society of Cardiology has officially endorsed His-bundle pacing (HBP) as an alternative to conventional right ventricular pacing because it not only achieves the therapeutic goal of treating bradyarrhythmia but also preserves left ventricular synchrony, thereby preventing or treating pacing-induced heart failure. When performing His-bundle pacing, a conduction delay of approximately 35–55 milliseconds are required for the electrical impulse to propagate to the ventricles and initiate depolarization. Consequently, in dual-chamber His-bundle pacemakers, the optimal atrioventricular (AV) conduction interval tends to be shorter than that of other pacing modalities. However, the exact degree of AV interval shortening required to achieve optimal synchronization remains uncertain.. Currently, two principal methods are utilized to optimize the AV conduction interval in patients with dual-chamber His-bundle pacing: (1) Doppler echocardiography, a low-cost and easily applicable technique, and (2) invasive cardiac catheterization with measurement of dP/dt_{max}, which is considered the gold standard but is more costly and invasive. Although both techniques have been implemented in several major centers, studies evaluating their correlation in the context of His-bundle pacing remain limited.

Therefore, to objectively assess the efficacy, safety, and determine the optimal atrioventricular conduction interval of dual-chamber His-bundle pacemakers in patients with atrioventricular block, we conducted the study entitled: **“Optimization of atrioventricular conduction interval using echocardiographic doppler and cardiac catheterization in patients with atrioventricular block undergoing His-bundle pacing.”**

2. Study objective

1. To investigate the clinical and paraclinical characteristics, as well as to determine the optimal atrioventricular conduction interval using Doppler echocardiography and invasive hemodynamic assessment, in patients with atrioventricular block who have undergone His-bundle pacemaker implantation.

2. To evaluate the therapeutic outcomes, quality of life, and major adverse cardiovascular events (MACE) associated with His-bundle pacing after optimization of the atrioventricular conduction interval.

3. Scientific and Practical Significance of the Dissertation

3.1. Scientific Significance

Optimization of the atrioventricular (AV) conduction interval after His-bundle pacemaker implantation plays a crucial role in enhancing atrioventricular synchrony, thereby optimizing stroke volume and cardiac output following cardiac resynchronization pacing. In the long term, this approach contributes to improved left ventricular ejection fraction and prevention of adverse cardiac remodeling.

This study aims to elucidate the scientific basis, accuracy, and degree of correlation between AV interval optimization using Doppler echocardiography and that determined by invasive left ventricular catheterization with dP/dt_{max} measurement.

Furthermore, the research provides scientific data on the clinical efficacy of His-bundle pacing optimized for atrioventricular conduction interval after six months of follow-up.

3.2. Practical Significance of the Study

This study will be translated into clinical practice to favor Doppler echocardiography–guided optimization of the atrioventricular (AV) conduction interval over invasive left-ventricular catheterization with dP/dt_{max} measurement in patients undergoing His-bundle pacing.

The research will also provide six-month outcomes in His-bundle–paced patients whose AV conduction interval has been optimized, thereby informing practice-oriented recommendations and identifying additional areas for improvement to enhance real-world clinical effectiveness.

4. Contributions of the Dissertation

This is one of the few studies comparing the correlation between two techniques for optimizing the atrioventricular conduction interval: Doppler echocardiography and invasive left ventricular catheterization with dP/dt_{max} measurement.

The study contributes to clinical practice by supporting the selection of

Doppler echocardiography for atrioventricular conduction interval optimization, as a non-invasive and cost-effective alternative to more invasive and expensive methods.

Furthermore, the research contributes to both Vietnamese and global cardiovascular medicine by providing scientific evidence and practical clinical insights in patients undergoing His-bundle pacing..

STRUCTURE OF THE DISSERTATION

The dissertation comprises 136 pages with 4 chapters, 48 tables, 32 figures, 1 diagram, and 9 charts. References total 126 documents (18 in Vietnamese and 108 in English). The Introduction covers 4 pages; the Literature Review, 32 pages; Research Subjects and Methods, 29 pages; Results, 33 pages; Discussion, 36 pages; Conclusion, 1 page; and Recommendations, 1 page.

CHAPTER 1: LITERATURE REVIEW

1.1. ANATOMY OF THE CARDIAC CONDUCTION SYSTEM AND CONDUCTION DISORDERS

1.1.1. Atrioventricular Conduction System

The atrioventricular conduction system consists of the atrioventricular (AV) node, the His bundle, the right and left bundle branches, and the Purkinje fiber network. The His bundle can be classified into three anatomic types: Type 1, coursing beneath the membranous part of the interventricular septum; Type 2, running within the muscular portion of the septum; and Type 3, located immediately beneath the endocardium

1.1.2. Electrophysiological Characteristics of the His Bundle

The His bundle has two key electrophysiological characteristics: its longitudinal dissociation and its rate-dependent conduction properties. The HV interval, which represents the time required for the electrical impulse to travel through the His–Purkinje system, normally ranges from 35 to 55 milliseconds.

1.2. RIGHT VENTRICULAR PACING, PACING-INDUCED CARDIOMYOPATHY, AND PHYSIOLOGICAL CARDIAC PACING

1.2.1. Mechanisms of Right Ventricular Pacing and Pacing-Induced Cardiomyopathy

Pacing-Induced Cardiomyopathy (PICM) is defined as a decline in left ventricular function resulting from right ventricular pacing of ≥20%, after exclusion of other potential causes. The condition is identified when one or more of the following criteria are met:

- A reduction in left ventricular ejection fraction (LVEF) of more than 10% compared with baseline;
- A decline in LVEF from ≥50% to ≤40%; or
- A decrease in LVEF of ≥5% in patients with baseline LVEF <50%.

1.2.3.3. His bundle pacing

His-Bundle Pacing (HBP) is defined as the direct capture and conduction of electrical impulses through the His bundle fibers themselves. The pacing site is located near the tricuspid annulus, either on the atrial or ventricular side, where a His potential can be recorded with a His–ventricular (HV) interval ≥ 35 milliseconds. Stimulation at this site results in His bundle depolarization, leading to QRS narrowing, preservation of electrical and mechanical synchrony, improvement in myocardial contractility, and a reduction in mitral regurgitation

1.3. OPTIMIZATION OF THE ATRIOVENTRICULAR CONDUCTION INTERVAL IN PATIENTS WITH HIS-BUNDLE PACING

1.3.4. Rationale for Atrioventricular Conduction Interval Optimization after His-Bundle Pacing

Studies have shown that a prolonged PR interval—reflecting atrioventricular dyssynchrony or suboptimal atrioventricular coordination—leads to reduced ventricular filling, decreased cardiac output, and diastolic mitral regurgitation. This condition is also associated with an increased risk of atrial fibrillation and a 39–51% higher rate of heart failure–related hospitalizations.

1.3.6. Definition of Atrioventricular Conduction Interval Optimization

This is the process of determining the most appropriate atrioventricular conduction time that allows complete ventricular filling, thereby optimizing stroke volume and minimizing presystolic mitral regurgitation.

1.3.7. Methods of Atrioventricular Conduction Interval Optimization

1.3.7.1. Cardiac Catheterization Method Using dP/dt_{max} Measurement

A pigtail diagnostic catheter is introduced into the left ventricle and connected to a pressure monitoring system, through which the dP/dt_{max} can be recorded. By adjusting different atrioventricular (AV) conduction intervals, various dP/dt_{max} values are obtained. The sensed AV (AVs) and paced AV (AVp) intervals are considered optimal when they yield the highest dP/dt_{max} value.

1.3.7.2. Optimization of the Atrioventricular Conduction Interval by Measuring the VTI of the E and A Wave Spectra of Mitral Inflow, Aortic Flow, or Ventricular Filling Time

Determining the optimal atrioventricular conduction interval allows the identification of the optimal VTI and diastolic filling time (DFT), as well as the optimal cardiac output, and vice versa. Changes in the atrioventricular conduction interval will result in corresponding changes in the VTI across the mitral or aortic valve or in the DFT. The AV interval is considered optimal when the VTI across the mitral valve, across the aortic valve, or the diastolic filling time reaches its maximal value..

CHAPTER 2: STUDY SUBJECTS AND METHODS

2.1. SUBJECTS AND INCLUSION CRITERIA

2.1.1. Inclusion Criteria:

Patients who underwent dual-chamber His-bundle pacemaker implantation at the Arrhythmia Department, Cho Ray Hospital, from March 2022 to March 2024. Eligible patients met the pacing indications according to the 2021 European Society of Cardiology (ESC) guidelines and exhibited one or more of the following findings on a standard 12-lead surface electrocardiogram (ECG):

- Third-degree atrioventricular (AV) block.
- Second-degree AV block Mobitz type II or high-grade second-degree AV block.
- Symptomatic syncope with trifascicular block or intermittent third-degree AV block.
- Alternating left and right bundle branch block.
- Patients who provided informed consent to participate in the study.

2.1.2. Exclusion Criteria:

- Transient AV block due to reversible causes.
- Severe systemic illness or hemodynamic instability.
- Local skin infection at the pacemaker implantation site.
- Patients who refused to participate

2.2. RESEARCH METHODS

2.2.1. Study Design:

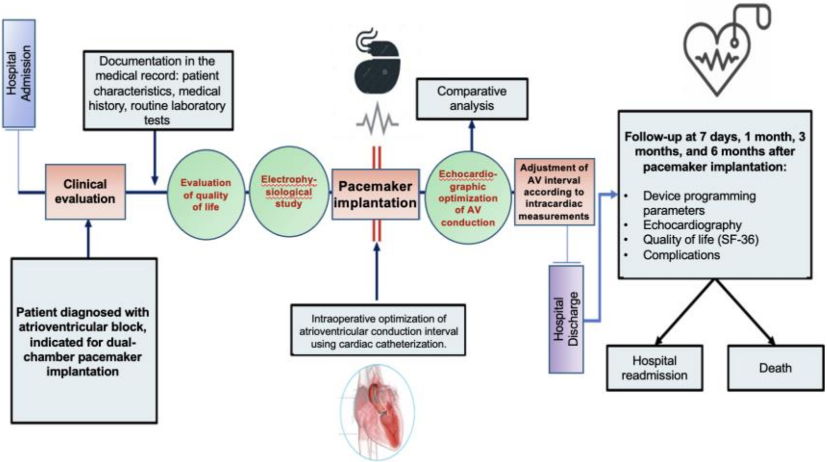
A prospective, interventional descriptive study with follow-up.

2.2.2. . Sample Size and Sampling Method:

Based on the study by Lan Su et al., the incidence of adverse events among patients with His-bundle pacing and a narrow QRS complex was 1.7%. Accordingly, the calculated sample size (n) was 26 patients. After adjusting for an estimated 10% loss to follow-up, the final required sample size was at least 29

2.3. STUDY PROCEDURE, RESEARCH PARAMETERS, AND IMPLEMENTATION

2.3.1. Research Flowchart



2.3.2. His-Bundle Pacemaker Implantation Procedure

Access is obtained via the axillary vein or subclavian vein. The His-bundle pacing catheter, featuring a double-curve design, is advanced over a guidewire into the right ventricle. Contrast injection is then performed to identify the location of the tricuspid annulus.

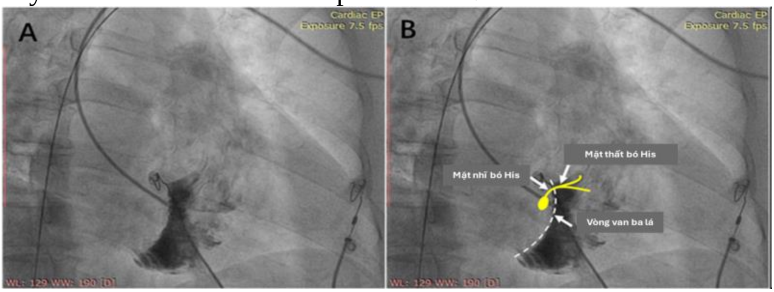


Figure 2.4: Contrast injection to identify the tricuspid valve position, facilitating more accurate localization of the His bundle.

Gently withdraw the catheter toward the atrioventricular (AV) groove while rotating it counterclockwise to ensure that the electrode tip approaches the septum perpendicularly at the basal portion of the tricuspid valve. Using a Pace-Sense Analyzer (PSA) or an electrophysiology recording system, identify and record the atrial–His–ventricular (A–H–V) signals. Once the His-bundle electrogram is detected, rotate the lead 4–5 turns clockwise while keeping the lead body straight to ensure proper torque transmission to the electrode tip. Check both unipolar and bipolar pacing thresholds, starting at 5 V / 1 ms, and gradually decrease the output to determine the pacing capture threshold. A pacing threshold below 1.5V/1ms is considered acceptable.

2.3.12. Atrioventricular Conduction Interval Optimization

2.3.12.2. Using the Cardiac Catheterization Method with dP/dtmax Measurement

Cardiac catheterization was performed in the DSA room immediately during pacemaker implantation. Each patient underwent the procedure only once to determine the optimal atrioventricular conduction interval, using invasive left ventricular dP/dt_{max} measurement as the gold-standard method**.**

+ Step 1: Introduction of the Pressure and dP/dt_{max} Measurement System into the Left Ventricle

Using the Seldinger technique, puncture the right femoral artery and advance a guidewire into the left ventricle. Over the guidewire, insert a pigtail diagnostic catheter into the left ventricular cavity and connect the catheter to the pressure monitoring system.

+ Determination of the Optimal AVs Using Invasive Left Ventricular dP/dtmax Measurement.

- The AVs interval is initially set as short as possible (40 ms) to ensure that the His bundle is depolarized by the pacemaker. The device is programmed in VDD mode at a pacing rate 10 beats per minute lower than the patient’s intrinsic sinus rate, ensuring that the His-bundle pacemaker captures only in response to the patient’s own sinus P wave.
- The atrioventricular conduction interval is then gradually increased in 20-ms increments. After each adjustment, a 20-second stabilization period is allowed before recording the left ventricular dP/dtmax for at least one respiratory cycle, and the mean dP/dtmax is calculated.
- After obtaining the mean dP/dtmax values for all tested AV intervals,

the optimal AVs is defined as the interval corresponding to the highest mean dP/dtmax.

+ Step 3: Determination of the Optimal AVp Using Invasive Left Ventricular dP/dtmax Measurement.

- The AVp interval is initially set as short as possible (60 ms) to ensure that the His bundle is depolarized by the pacemaker. The device is programmed in DDD mode (pacing and sensing in both atrial and ventricular chambers) at a pacing rate 10 beats per minute higher than the patient's intrinsic heart rate, ensuring that the pacemaker stimulates both the atrium and the His bundle.
- The atrioventricular conduction interval is then gradually increased in 20-ms increments. After each adjustment, a 20-second stabilization period is allowed before recording the left ventricular dP/dtmax for at least one respiratory cycle, and the mean dP/dtmax is calculated.
- After obtaining the mean dP/dtmax values for all tested AV intervals, the optimal AVp is defined as the interval corresponding to the highest mean dP/dtmax.

2.3.12.3. Method of Atrioventricular Conduction Interval Optimization Using Doppler Echocardiography by Measuring Mitral Valve VTI

Doppler echocardiography–guided optimization was performed within 24 hours after the procedure, once the patient had returned to the ward. This approach was used to assess the correlation between echocardiographic optimization and invasive cardiac catheterization, with the aim of identifying Doppler echocardiography as a potential alternative method for atrioventricular conduction interval optimization when invasive catheterization is not feasible..

+ Step 1: Determination of the Optimal AVs Using Doppler Echocardiography with Diastolic Mitral Valve VTI Measurement

- The AVs interval is initially set as short as possible (40 ms) to ensure that the His bundle is depolarized by the pacemaker. The device is programmed in VDD mode at a pacing rate 10 beats per minute lower than the patient's intrinsic heart rate, ensuring that the His-bundle pacemaker captures only in response to the patient's sinus P wave.
- The atrioventricular conduction interval is then gradually increased in 20-ms increments. After each adjustment, at least 20 cardiac cycles are allowed before measuring the diastolic mitral inflow VTI in the apical four-chamber view, placing the pulsed-wave Doppler sample volume at the tip of the mitral valve leaflets to obtain the E-A wave

spectrum during diastole. The automatic VTI measurement program is used to trace the contour of the E-A wave envelope at end-expiration, and the measurement is repeated three times for each AV interval. The mean diastolic mitral inflow VTI is then calculated.

- The optimal AVs is defined as the interval corresponding to the highest mean diastolic mitral inflow VTI.

+ Step 2: Determination of the Optimal AVp Using Doppler Echocardiography with Diastolic Mitral Valve VTI Measurement

- The AVp interval is initially set as short as possible (60 ms) to ensure that the His bundle is depolarized by the pacemaker. The device is programmed in DDD mode at a pacing rate 10 beats per minute higher than the patient's intrinsic heart rate, ensuring that the pacemaker stimulates both the atrium and the His bundle.
- The atrioventricular conduction interval is then gradually increased in 20-ms increments. After each adjustment, at least 20 cardiac cycles are allowed before measuring the diastolic mitral inflow VTI in the apical four-chamber view, with the pulsed Doppler sample volume positioned at the tip of the mitral valve leaflets to record the E-A wave spectrum during diastole.
- The automatic measurement program is used to trace the contour of the E-A wave envelope at end-expiration, and the measurement is repeated three times for each AV interval. The mean diastolic mitral inflow VTI is then calculated.
- The optimal AVp is defined as the interval corresponding to the highest mean diastolic mitral inflow VTI

2.3.12.4. . Method of Atrioventricular Conduction Interval Optimization Using Doppler Echocardiography with Systolic Aortic Valve VTI Measurement

Performed within 24 hours after the procedure, this method is conducted in a manner like the technique using mitral valve VTI measurement, except that the systolic aortic valve VTI is measured instead of the mitral inflow VTI. The optimal AVs and AVp intervals are determined based on the highest mean systolic aortic valve VTI values.

2.3.12.5. Method of Atrioventricular Conduction Interval Optimization Using Ventricular Filling Time Measurement

Performed within 24 hours after the procedure

+ Step 1: Determination of the Optimal AVs Using the Ventricular Filling Time (DFT) Measurement Method

- The AV interval is initially set as short as possible (40 ms) to ensure that the His bundle is depolarized by the pacemaker. The device is programmed in VDD mode at a pacing rate 10 beats per minute lower than the patient's intrinsic heart rate, ensuring that the His-bundle pacemaker captures only in response to the patient's sinus P wave to determine the optimal AVs.
- The atrioventricular conduction interval is then gradually increased in 20-ms increments. After each adjustment, at least 20 cardiac cycles are allowed before measuring the diastolic filling time (DFT) of the mitral inflow in the apical four-chamber view, placing the pulsed Doppler sample volume at the tip of the mitral valve leaflets to record the E–A wave spectrum during diastole. The measurement program is used to determine the time interval from the beginning of the E wave to the end of the A wave, with three measurements obtained for each AV interval, and the mean DFT is calculated.
- The optimal AVs is defined as the interval corresponding to the highest mean DFT.

+ Step 2: Determination of the Optimal AVp Using Doppler Echocardiography with DFT Measurement

- The AVp interval is initially set as short as possible (60 ms) to ensure that the His bundle is depolarized by the pacemaker. The device is programmed in DDD mode at a pacing rate 10 beats per minute higher than the patient's intrinsic heart rate, ensuring that both the atrium and the His bundle are stimulated.
- The atrioventricular conduction interval is then gradually increased in 20-ms increments. After each adjustment, at least 20 cardiac cycles are allowed before measuring the DFT of the mitral inflow in the apical four-chamber view, with the pulsed Doppler sample volume positioned at the tip of the mitral valve leaflets to obtain the E–A wave spectrum during diastole.
- The measurement program is used to determine the time interval from the beginning of the E wave to the end of the A wave, with three measurements obtained for each AV interval, and the mean DFT is calculated.
- The optimal AVp is defined as the interval corresponding to the highest mean DFT.

2.3. DATA ANALYSIS

Data were analyzed using SPSS version 26.0.

Qualitative variables were presented as frequencies and percentages. Quantitative variables with a normal distribution were expressed as mean ± standard deviation (SD), while those without a normal distribution were expressed as median (interquartile range: Q1–Q3).

The Chi-square test (with Fisher's exact correction when appropriate) was used to compare proportions. The paired t-test was applied to compare normally distributed quantitative variables at two different time points, and ANOVA was used for comparisons involving more than two variables. For non-normally distributed quantitative variables, the Wilcoxon test was applied.

The Pearson correlation coefficient was used to assess the relationship between two normally distributed quantitative variables, whereas the Spearman correlation coefficient was used for non-normally distributed quantitative variables.

A p-value < 0.05 was considered statistically significant, with a 95% confidence interval (CI)

2.4. RESEARCH ETHICS

The Ethics Committee of Hue University of Medicine and Pharmacy approved the implementation of this study under Decision No. H2022/504.

The indication for His-bundle pacemaker implantation in all patients was approved by the Board of Directors of Cho Ray Hospital.

The indication for His-bundle pacing was based on the guidelines and recommendations of the European Society of Cardiology (ESC).

The selection of the pacemaker manufacturer was made according to the patient's preference after they had been fully informed about the efficacy and technical features of the His-bundle pacemaker.

Patients and/or their family members:

- Were informed of the study's purpose and procedures.
- Signed the written informed consent form prior to participation.

All tests and assessments were performed concurrently with standard diagnostic and therapeutic procedures and caused no harm to the patients.

All patient information was used solely for research purposes and not for any other intent...

CHAP TER 3: STUDY RESULTS

3.1. CLINICAL AND SUBCLINICAL CHARACTERISTICS

The study included 60 patients, of whom 60% were female, with a mean age of 59.03 ± 18.86 years. Atrioventricular block located proximal to or at the His bundle was observed in 95% of patients. A wide QRS complex was present in 31.7% of cases, and 16.7% of patients had a left ventricular ejection fraction below 55%. The mean body mass index was 21.79 ± 3.29 kg/m². The most common reason for hospital admission was fatigue, accounting for 40% of cases. Syncope was the most frequent presenting symptom, occurring in 42 of 60 patients. Only 11.7% (7 patients) had underlying cardiomyopathies, predominantly ischemic cardiomyopathy. The most common comorbidities among patients undergoing His-bundle pacing at Cho Ray Hospital were hypertension (51.7%), dyslipidemia (26.7%), with a mean baseline LDL-cholesterol level of 99.16 ± 42.78 mg/dL, and type 2 diabetes mellitus (20.6%), with a mean baseline blood glucose level of 123.88 ± 58.18 mg/dL.

Table 0.1: HBP indication based on 12 leads ECG

Characteristics		**Incidence**	**Percentage (%)**
HBP indication	Complete third degree AV Block	40	66,7
	Secon degree AV Block	17	28,3
	Intermittent third degree AV block	03	5

Table 3.13: His-Bundle Branch Pacing Thresholds during the Procedure

		n (%)	**Threshold (V)**
Non-selective His capture	**Unipolar**	43/71 (60,56%)	0,73 ± 0,27
	Bipolar	43/71 (60,56%)	0,77 ± 0,28

3.2. OPTIMAL ATRIOVENTRICULAR CONDUCTION INTERVAL DETERMINED BY DOPPLER ECHOCARDIOGRAPHY AND CARDIAC CATHETERIZATION IN PATIENTS WITH ATRIOVENTRICULAR BLOCK UNDERGOING HIS-BUNDLE PACING

These patients underwent atrioventricular conduction interval optimization using invasive interventional cardiac catheterization performed during the implantation procedure. Femoral arterial access was obtained, and a pigtail catheter was advanced retrogradely through the aorta into the left ventricular cavity. After completion of pacemaker implantation and cardiac catheterization, patients were transferred to the ward for overnight observation. Transthoracic echocardiography was subsequently performed to determine the optimal atrioventricular conduction interval and to assess the correlation between echocardiography-based optimization and the gold-standard invasive dP/dt_{max}–based catheterization method. The atrioventricular conduction interval was then programmed according to the optimal values determined by invasive cardiac catheterization.

3.2.2.1. Comparison of the Correlation between Atrioventricular Conduction Interval Optimization Methods after His-Bundle Pacing Using Invasive Cardiac Catheterization with dP/dt_{max} Measurement and Doppler Echocardiography with Mitral Valve VTI Measurement

Table 3.22: Correlation between Invasive Cardiac Catheterization with dP/dtmax Measurement and Doppler Echocardiography with Mitral Valve VTI Measurement in His-Bundle Pacing Optimization

Optimization Method	(1) dP/dt_{max} (n = 60)	(2) VTI_{V2L} (n = 60)
Optimal AVs Interval (ms)	115 ± 40,44	99,66 ± 30,69
Spearman Correlation Coefficient	*rho = 0,452 (p < 0,0001)*	

Table 3.23: Correlation between Invasive Cardiac Catheterization with dP/dtmax Measurement and Doppler Echocardiography with Mitral Valve VTI Measurement during Atrial and His-Bundle Pacing

Optimization Method	(1) dP/dt_{max} (n = 60)	(2) VTI_{V2L} (n = 60)
Optimal AVp Interval (ms)	169,00 ± 34,03	158,66 ± 29,42
Spearman Correlation Coefficient	rho = 0,334 (p = 0,009)	

3.2.2.2. Comparison of the Correlation between Atrioventricular Conduction Interval Optimization Methods after His-Bundle Pacemaker Implantation Using Invasive Cardiac Catheterization with dP/dtmax Measurement and Doppler Echocardiography Measuring VTI through the Aortic Valve

Table 3.24: Correlation between Invasive Cardiac Catheterization with dP/dtmax Measurement and Doppler Echocardiography Measuring Aortic Valve VTI during His-Bundle Pacing

Optimization Method	(1) dP/dtmax	(2) $VTI_{ĐMC}$

	(n = 60)	(n = 60)
Optimal AVs Interval (ms)	115 ± 40,44	103,81 ± 32,30
Spearman Correlation Coefficient	rho = 0,406 (p = 0,001)	

Table 3.25: Correlation between Invasive dP/dtmax-Based Optimization and Doppler Echocardiography Measuring Aortic Valve VTI during Atrial and His-Bundle Pacing

Optimization Method	(1) dP/dtmax (n = 60)	(2) $VTI_{ĐMC}$ (n = 60)
Optimal AVp Interval (ms)	169,00 ± 34,03	163,00 ± 24,92
Spearman Correlation Coefficient	rho = 0,342 (p = 0,007)	

3.2.2.3. Comparison of the Correlation between Atrioventricular Conduction Interval Optimization Methods after His-Bundle Pacemaker Implantation Using Invasive Cardiac Catheterization with dP/dtmax Measurement and Doppler Echocardiography Measuring Ventricular Filling Time through the Mitral Valve

Table 3.26: Correlation between Invasive Cardiac Catheterization with dP/dtmax Measurement and Doppler Echocardiography Measuring Ventricular Filling Time (DFT) through the Mitral Valve during His-Bundle Pacing

Optimization Method	(1) dP/dtmax (n = 60)	(2) DFT_{V2L} (n = 60)
Optimal AVs Interval (ms)	115 ± 40,44	*101,33 ± 28,96*
Spearman Correlation Coefficient	rho = 0,291 (p = 0,024)	

+ Correlation during Atrial and His-Bundle Pacing

Table 3.27: Correlation between Invasive Cardiac Catheterization with dP/dtmax Measurement and Doppler Echocardiography Measuring Ventricular Filling Time during Atrial and His-Bundle Pacing

Optimization Method	(1) dP/dt_{max} (n = 60)	(2) DFT_{V2L} (n = 60)
Optimal AVp Interval (ms)	169,00 ± 34,03	164,00 ± 29,18

Spearman Correlation Coefficient	rho = 0,386 (p = 0,002)

3.2.3. Comparison of the Optimal Atrioventricular Conduction Intervals Determined by Different Optimization Methods

Table 3.28: Comparison of the Correlation between Doppler Echocardiography Optimization Methods and Invasive Cardiac Catheterization with dP/dt_{max} Measurement

When pacing His bundle only (AsVp)	When pacing atrium and His bundle (ApVp)
Optimization using mitral valve VTI (ρ = 0.458) > Optimization using aortic valve VTI (ρ = 0.406) > Optimization using mitral valve DFT (ρ = 0.291)	Optimization using mitral valve DFT (ρ = 0.386) > Optimization using aortic valve VTI (ρ = 0.342) > Optimization using mitral valve VTI (ρ = 0.334)

Table 3.32: Effects of pacing on invasive hemodynamics and echocardiographic parameters after AVsens optimization

Catheterization	Before pacing	After pacing	After pacing and AV sens optimization	Increase after optimization	Contribution due to optimization	p
Cardiac contractility dP/dt_{max} (mmHg/s)	1412,80 ± 449,47	1625,42 ± 471,74	1666,26 ± 497,29	253,46 ± 284,00 (21,39 ± 26,43%)	40,84 ± 74,94 (3,00 ± 5,51%)	p_{pre} <0,0001 $p_{AVoptimize}$ <0,0001
Left ventricular peak systolic pressure (mmHg)	140,27 ± 26,38	148,63 ± 26,57	150,08 ± 26,42	9,81 ± 12,67 (7,61 ± 10,01%)	1,45 ± 3,98 (1,06 ± 2,67%)	p_{pre} <0,0001 $p_{AVoptimize}$ <0,0001
Aortic systolic pressure (mmHg)	145,13 ± 24,59	150,35 ± 26,85	150,83 ± 27,44	5,69 ± 1,61 (4,05 ± 8,19%)	0,47 ± 3,72 (0,32 ± 3,73%)	p_{pre} <0,0001 $p_{AVoptimize}$ <0,0001

Mean aortic pressure (mmHg)	95,57 ± 15,41	106,42 ± 16,63	105,59 ± 15,36	10,01 ± 14,45 (11,89 ± 17,36%)	-0,82 ± 7,78 (0,91 ± 9,52%)	p_{pre}<0,0001 $p_{AVoptimize}$<0,001
VTI_{Mitral} (cm)	16,13 ± 4,63	17,06 ± 4,95	18,34 ± 5,03	2,21 ± 2,64 (15,61 ± 19,65%)	1,28 ± 2,82 (9,52 ± 19,5%)	p_{pre}<0,0001 $p_{AVoptimize}$<0,0001
VTI_{AO} (cm)	24,03 ± 6,40	25,10 ± 6,10	26,72 ± 7,10	2,68 ± 4,24 (5,31 ± 8,61%)	1,61 ± 4,47 (7,22 ± 19,95%)	p_{pre}<0,0001 $p_{AVoptimize}$<0,0001
DFT_{Mitral} (ms)	358,52 ± 84,59	377,84 ± 76,75	396,68 ± 75,67	38,16 ± 58,31 (13,77 ± 23,04%)	18,84 ± 49,76 (6,63 ± 18,57%)	p_{pre}<0,0001 $p_{AVoptimize}$<0,0001

3.3.4.1. Changes on echocardiography in patients with His-bundle pacing

Table 0.2: Changes on echocardiography

Echocardiographic parameters	**Before the procedure (0)**	**After 1 month (1)**	**After 3 months (2)**	**After 6 months (3)**	**p**
	n = 60	n = 57	n = 57	n = 57	
Left ventricular end-diastolic diameter (mm)	47,18 ± 7,30	46,22 ± 6,66	46,10 ± 6,10	45,06 ± 5,77	p (0&1) > 0,05 p (0&2) > 0,05 p (0&3) > 0,05
Left ventricular end-diastolic volume (mL)	104,70 ± 42,13	101,45 ± 35,98	100,26 ± 32,23	94,91 ± 27,84	p (0&1) > 0,05 p (0&2) > 0,05 p (0&3) > 0,05
Left ventricular ejection fraction (%)	64,16 ± 12,90	63,02 ± 9,21	64,05 ± 9,66	64,78 ± 8,21	p (0&1) > 0,05 p (0&2) > 0,05 p (0&3) > 0,05

3.3.4.2. . Changes in Echocardiographic Findings in Heart Failure Patients Implanted with His-Bundle Pacemaker

Table 0.3: Changes in Echocardiographic Parameters in Heart Failure Patients Implanted with His-Bundle Pacemaker

Before the procedure (1)	After 1 month (2)	After 3 months (3)	After 6 months (4)	p *(Wilcoxon test)*
n = 10	n = 10	n = 10	n = 10	
41,93 ± 11,33	52,02 ± 11,02	50,90 ± 10,58	55,80 ± 8,50	p (0&1) = 0,006 p (0&2) = 0,005 p (0&3) = 0,001

3.3.5. Changes in Quality of Life

Table 0.4: Changes in Quality of Life

Quality of life	Before the procedure	After 6 months	Changes	p (Wilcoxon)
	n = 68	n = 68		
Physical quality of life	48,97 ± 22,49	72,64 ± 13,98	23,95 ± 23,51	p < 0,0001
Mental quality of life	52,5 ± 22,59	72,01 ± 9,78	19,6 ± 21,52	p < 0,0001

Table 3.44: Complications within 6 Months after His-Bundle Pacing Procedure

MACE	Number of patients	Percentage (%)
Loss of pacing lead capture	3/71	4,2
The pacing threshold of the lead increased to >3 V	1/71	1,4

CHAPTER 4: DISCUSSION

4.1. CLINICAL AND SUBCLINICAL CHARACTERISTICS

In our study, 107 patients with indications for His-bundle pacemaker implantation were screened. Successful implantation was achieved in 71 patients. Among these 71 patients, only 60 consented to undergo cardiac catheterization for atrioventricular conduction interval optimization and were therefore included in the final analysis. The study population comprised 36 female patients, accounting for 60%. The mean age was 59.03 ± 18.86 years. Pre-His atrioventricular block was present in 73.3% of patients; 31.7% had a wide QRS complex, and 10 patients (16.7%) had a left ventricular ejection fraction below 55%. Compared with other studies, several observations regarding the characteristics of our study population can be noted as follows:

4.1.5. Selective and Non-Selective His-Bundle Pacing Thresholds

The His-bundle pacing (HBP) capture threshold is a key parameter of interest and is routinely reported in most studies on His-bundle pacing. In a study by Vijayaraman et al. (2016), the acute pacing threshold was 1.75 ± 0.7 V/0.5 ms in patients without a His injury current, compared with 1.16 ± 0.4 V/0.5 ms in those with a His injury current. At 1-year follow-up, the pacing threshold was 1.98 ± 0.9 V/0.5 ms in the group without a His injury current, versus 1.30 ± 0.6 V/0.5 ms in the group with a His injury current. The authors concluded that the presence of a His injury current is an important predictor of achieving a low and stable pacing threshold. Sharma et al. (2017) reported an HBP threshold of 1.4 ± 0.9 V. Zanon et al. reported an acute HBP threshold of 1.6 V, increasing to 2.0 V after 2 years of follow-up [122]. Lan Su et al. (2019) reported an HBP threshold of 0.85 ± 0.51 V/0.5 ms [110].

In our study, the selective His-bundle pacing threshold ranged from 0.69 ± 0.22 V (selective unipolar HBP) to 0.73 ± 0.23 V (selective bipolar HBP). The non-selective His-bundle pacing threshold was 1.48 ± 0.83 V (non-selective unipolar HBP) and 1.53 ± 0.84 V (non-selective bipolar HBP). Overall, the pacing thresholds in our study were lower than those reported by Vijayaraman, Sharma, and Zanon, and were comparable to the findings of Lan Su. These differences or similarities may be attributable to procedural technique. Because the His bundle is a very small structure with a diameter of only 2–3 mm, successful HBP requires precise lead fixation (lead diameter 1.3–2.0 mm) at the correct site and depth to ensure effectiveness and long-term stability. To optimize lead placement, we applied several technique-based strategies derived from prior studies and practical experience: (1) marking the His-bundle location using an electrophysiology mapping catheter; (2) using two His-bundle pacing leads when necessary; (3) prioritizing sites with a His injury current; (4) prioritizing sites where His capture can be achieved prior to active fixation with a pacing output of 2–5 V; and (5) repositioning the lead if the pacing threshold increases by more than 0.5 V/1 ms after sheath removal and if the post-sheath threshold exceeds 1.5 V/1 ms. With the integration of experience from multiple centers and the accumulated learning during implementation, the low His-bundle pacing thresholds observed in our study are consistent with those reported in the international literature.

4.2. THE OPTIMAL ATRIOVENTRICULAR CONDUCTION INTERVAL DETERMINED BY DOPPLER ECHOCARDIO-GRAPHY AND CARDIAC CATHETERIZATION IN PA-TIENTS WITH ATRIOVENTRICULAR BLOCK UNDER-GOING HIS-BUNDLE PACING

Recently, conduction system pacing has been routinely implemented in many centers and is increasingly becoming a standard pacing strategy to minimize pacing-induced heart failure. Therefore, it is necessary to re-evaluate the role of atrioventricular conduction interval optimization in patients who have undergone conduction system pacing, such as His-bundle pacing.

4.2.1 The Optimal Atrioventricular Conduction Interval.

4.2.1.1 The Optimal Atrioventricular Conduction Interval Determined by Invasive Left Ventricular dP/dtmax Measurement

The study by Nguyen Tri Thuc and Hoang Anh Tien reported that the optimal atrioventricular (AV) conduction interval in patients undergoing physiologic pacing, when determined using invasive cardiac catheterization with left ventricular dP/dt_{max} measurement, was 115.39 ± 9.18 ms [13]. In Stanton's review (2008) [108], analysis of the PATH-CHF study (2005) showed an optimal AV interval of 112 ± 33 ms, and PATH-CHF II (2006) reported 119 ± 32 ms [108]. Jansen (2006) reported an optimal AV interval of 120 ± 26 ms using invasive dP/dt_{max} measurement [55]. In our study, the optimal AV interval determined by invasive left ventricular dP/dt_{max} catheterization was 115 ± 40.44 ms. Thus, our optimal AV interval is consistent with the findings reported by the above authors.

A plausible explanation is that physiologic pacing in our study was achieved through His-bundle pacing, which requires a finite conduction time for electrical impulses to propagate to the ventricular myocardium. Therefore, the programmed AV interval in our patients needs to be shorter; however, the effective PR interval may appear longer because, in selective His-bundle pacing, an isoelectric interval exists after His capture before the onset of the QRS complex.

In contrast, Auricchio (1999) reported an optimal AV interval of 98 ± 52 ms based on invasive dP/dt_{max} assessment [108], which differs substantially from our findings. This discrepancy may be explained by differences in optimization strategy: Auricchio performed optimization of both AV and VV intervals, whereas our study focused solely on AV interval optimization..

4.2.1.2 The Optimal Atrioventricular Conduction Interval Determined by Doppler Echocardiography Using the Aortic Valve Systolic VTI Measurement

Our study showed that when optimizing the atrioventricular (AV) conduction interval using Doppler echocardiography with an aortic valve VTI–based approach, the optimal AV interval was 103.81 ± 32.30 ms. Nguyen Tri Thuc and Hoang Anh Tien reported an optimal AV interval of 115.39 ± 10.02 ms. Kerlan (2006) [68] reported an optimal AV interval of 119 ± 34 ms. Therefore, our findings suggest that AV intervals optimized by Doppler echocardiography using aortic valve VTI tend to be shorter than those reported by Gyalai, Kerlan, and Nguyen Tri Thuc and Hoang Anh Tien. This is clinically plausible because His-bundle pacing requires additional conduction time for impulses to propagate from the His bundle to the ventricular myocardium; consequently, the programmed optimal AV interval in His-bundle pacing generally needs to be shorter than that used with other pacing modalities.

4.2.1.3. The Optimal Atrioventricular Conduction Interval Determined by Doppler Echocardiography Using the Mitral Valve Diastolic E–A Wave VTI Measurement

In our study, the optimal atrioventricular (AV) conduction interval determined using Doppler echocardiography with mitral inflow E–A VTI measurement during diastole was 101.33 ± 28.96 ms. In the study by Nguyen Tri Thuc and Hoang Anh Tien, the corresponding value was 116.45 ± 8.76 ms. Gyalai reported an optimal AV interval of 115.91 ± 26.53 ms [50]. Our findings therefore indicate that a shorter programmed AV interval is required compared with those reported by Nguyen Tri Thuc and Hoang Anh Tien and by Gyalai. This difference may be explained by variation in physiologic pacing techniques, particularly between biventricular (three-chamber) pacing and His-bundle pacing.

4.2.1.4. The Optimal Atrioventricular Conduction Interval Determined by Ventricular Filling Time Optimization

Salden (2022) reported that the optimal atrioventricular (AV) conduction interval determined by ventricular filling time optimization was 137 ± 30 ms. In our study, ventricular filling time–guided optimization yielded an optimal AV interval of 101.33 ± 28.96 ms. This difference may be explained by variations in the study population and methodology. In

Salden's study, the population consisted of heart failure patients with prolonged PR intervals. In His-bundle pacing, the programmed AV interval determines the timing between atrial pacing and His capture, while conduction from the His bundle to the ventricles typically requires 35–55 ms. Therefore, when comparing effective AV/PR timing, our results are broadly consistent with those reported by Salden.

4.2.2. The Correlation among Optimization Techniques

4.2.2.1 Correlation between Atrioventricular Conduction Interval Optimization Determined by Invasive dP/dtmax Measurement and Doppler Echocardiographic Mitral Valve VTI.

Coluccia (2023) demonstrated that atrioventricular (AV) conduction interval optimization using Doppler echocardiography was positively correlated with the gold-standard method and achieved an accuracy of up to 71.8% [35]. Jansen reported a strong positive correlation between the two methods, with a correlation coefficient of $r = 0.96$. Nguyen Tri Thuc also reported a correlation coefficient of $r = 0.941$. In our study, invasive cardiac catheterization with dP/dt_{max} measurement showed a positive correlation with Doppler echocardiography–guided optimization using mitral inflow VTI. During His-bundle pacing tracking intrinsic sinus P waves, the Spearman correlation coefficient was rho = 0.452 ($p < 0.0001$), with the correlation equation $y = 0.3181x + 63.081$. During combined atrial and His-bundle pacing, the correlation coefficient was rho = 0.334 ($p < 0.05$), with the correlation equation $y = 0.2447x + 117.32$. However, our correlation coefficients were lower than those reported by Jansen and Nguyen Tri Thuc. This discrepancy may be attributable to differences in study populations

4.2.2.2. . Comparison of the Correlation between Atrioventricular Conduction Interval Optimization Using Invasive dP/dtmax Measurement and Doppler Echocardiographic Aortic Valve VTI.

Studies by Kerlan and Bui Vinh Ha demonstrated that programming CRT devices using an optimized AV interval determined by Doppler echocardiography with an aortic VTI–based approach improves dP/dt_{max}. Jansen (2006) reported that Doppler echocardiography–guided optimization using aortic valve VTI was positively correlated with invasive left ventricular dP/dt_{max}–based optimization, with a correlation coefficient of 0.56. Nguyen Tri Thuc and Hoang Anh Tien reported correlation coefficients of 0.563 during biventricular pacing and 0.626 during atrial plus biventricular pacing (three-chamber pacing). In our study, the correlation coefficient for AV interval optimization during selective His-bundle pacing with atrial sensing (AVs) was rho = 0.406 (p = 0.001). During atrial and His-bundle pacing (AVp), the correlation coefficient was rho = 0.342 (p = 0.007). Thus, consistent with prior studies, our findings support the use of Doppler echocardiography with aortic valve VTI measurement to optimize both AVs and AVp intervals. However, the correlation observed in our study was lower than that reported by Jansen and by Nguyen Tri Thuc and colleagues. This difference may be explained by disparities in study populations: Jansen and Nguyen Tri Thuc primarily investigated heart failure patients with reduced ejection fraction, whereas our cohort largely consisted of patients without heart failure who required pacing for bradyarrhythmia indications..

4.2.2.3. Comparison of the Correlation between Atrioventricular Conduction Interval Optimization Using Invasive dP/dtmax Measurement and Doppler-Derived Ventricular Filling Time.

Meluzín (2004) reported that the optimal AV interval determined using left ventricular filling time optimization was positively correlated with cardiac output measured by a Swan–Ganz catheter. Jansen (2006) evaluated the correlation between left ventricular filling time optimization and invasive left ventricular dP/dt_{max}–based catheterization and reported a correlation coefficient of 0.83. Our findings are directionally consistent with Jansen's results, demonstrating a positive correlation with invasive dP/dt_{max} assessment. Specifically, the correlation coefficient for AV interval optimization during selective His-bundle pacing with atrial sensing (AVs) was rho = 0.291 (p = 0.024), and during atrial plus His-bundle pacing (AVp) was rho = 0.386 (p = 0.002). Therefore, in patients undergoing His-bundle pacing, atrioventricular conduction interval optimization based on ventricular filling time may be used as an alternative to invasive cardiac catheterization when invasive assessment is not feasible. Differences in correlation strength across studies may be attributable to variations in study populations (heart failure vs. non–heart failure cohorts) and differences in physiologic pacing modalities (biventricular/three-chamber pacing vs. His-bundle pacing).

4.3. OUTCOMES AFTER HIS-BUNDLE PACEMAKER IMPLANTATION, ATRIOVENTRICULAR CONDUCTION INTERVAL OPTIMIZATION, AND CONDUCTION SYSTEM PACING PARAMETERS

4.3.1. Effects on Ventricular Depolarization and Repolarization

4.3.1.1. Changes in QRS Duration after His-Bundle Pacing

The primary mechanism of His-bundle pacing is to recruit the His–Purkinje system to produce synchronized ventricular activation, thereby narrowing the QRS complex and/or correcting intraventricular conduction disturbances.

Vijayaraman reported a baseline QRS duration of 122 ± 27 ms, with a paced QRS duration of 124 ± 22 ms after His-bundle pacing. In Sharma's study (2015), baseline QRS duration in the His-bundle pacing group was 109 ± 26 ms; after implantation, the His-bundle pacing group had a significantly narrower QRS compared with right ventricular pacing, and the paced QRS duration was 124 ± 22 ms. In our study, baseline QRS duration was 103.86 ± 24.12 ms. After implantation, QRS duration significantly decreased to 96.06 ± 11.89 ms ($p < 0.05$).

Thus, His-bundle pacing in our cohort was associated with QRS narrowing compared with baseline, supporting its potential to enhance ventricular resynchronization through electrical synchronization. Differences from other studies may be related to variations in the study population, particularly the lower proportion of patients with intraventricular conduction delay and complete left bundle branch block in our cohort..

4.3.2. . Immediate Hemodynamic Effects after His-Bundle Pacing and Atrioventricular Conduction Interval Optimization

His-bundle pacing provides synchronized depolarization of both cardiac chambers, which is a major advantage over left bundle branch pacing, as the latter primarily ensures synchronization within the left ventricle only [109].

Recent studies have suggested that an improvement in dP/dt_{max} of >10% is associated with favorable clinical response and reverse remodeling, and that improved dP/dt_{max} is linked to a lower risk of rehospitalization and all-cause mortality. Sohaib (2015) investigated atrioventricular (AV) interval optimization in heart failure patients with prolonged PR intervals using His-bundle pacing, biventricular pacing, and right ventricular pacing, with AV interval optimization applied across pacing modes. The study showed that His-bundle pacing did not widen the QRS complex (QRS increased by 0.5 ms) and increased systolic blood pressure by 4.3 mmHg. Keene D (2020) similarly reported that His-bundle pacing did not widen the QRS compared with right ventricular pacing and improved systolic blood pressure by 5 mmHg ($p < 0.0001$) compared with the pre-optimization state

[65]. In our study, after His-bundle pacemaker implantation and AV interval optimization, invasive aortic systolic pressure increased by 5.69 ± 1.61 mmHg and mean aortic pressure increased by 10.01 ± 14.45 mmHg. Cardiac contractility increased by 21.39%. Differences across studies may be related to variations in study populations; for example, Salden's cohort consisted of heart failure patients, whereas most patients in our study did not have heart failure.

Hoyt (2022) reported that His-bundle pacing or biventricular pacing improved left ventricular contractility by 17%, and that only His-bundle pacing improved all three parameters of left ventricular performance, including invasive dP/dt_{max}, left ventricular pre-ejection period, and a cardiac function index. Kato (2021) demonstrated that His-bundle pacing produced an immediate improvement in cardiac function comparable to cardiac resynchronization therapy, with invasive left ventricular dP/dt_{max} increasing by 18.8% ± 6.4%. The magnitude of contractility improvement in Hoyt's and Kato's studies was somewhat lower than that observed in our study, which may be explained by differences in baseline characteristics. In Hoyt's study, patients had atrial fibrillation, underwent atrioventricular node ablation, and received His-bundle pacing, whereas patients in our study were in sinus rhythm and underwent His-bundle pacemaker implantation, leading to differences in atrial function and atrioventricular synchrony.

4.3.3. Evaluation of Cardiac Function by Doppler Echocardiography

Fry (2023) reported that the optimal atrioventricular (AV) intervals were 120 ms and 150 ms. With optimal AV programming, left ventricular outflow tract (LVOT) VTI increased by 21.3%, and the diastolic filling time ratio (EA/RR) increased by 31.5%. In our study, after pacing and AV interval optimization, LVOT VTI increased by 5.31 ± 8.61%, and ventricular filling time increased by 13.77 ± 23.04%. Therefore, the magnitude of improvement in LVOT VTI and ventricular filling time in our cohort appears lower than that reported by Fry. This difference may be related to the limited sample size in Fry's study (n = 10), which may not fully represent the spectrum of changes in LVOT VTI and filling time compared with our larger cohort.

Salden (2022) demonstrated that ventricular filling time optimization reduced diastolic mitral regurgitation and increased mean aortic pressure by 15%. In our study, mean aortic pressure increased by 10.01 ± 14.45 mmHg, corresponding to an increase of 11.89 ± 17.36%.

Ajijola, Sharma, and Upadhyay used His-bundle pacing as an alternative to CRT. After 12 months, left ventricular ejection fraction (LVEF) increased from 27 ± 10% to 41 ± 13% ($p < 0.001$) in Ajijola's study, from 30 ± 10% to 43 ± 13% ($p = 0.0001$) in Sharma's study, and by +7.2% [5.0–16.9%] in Upadhyay's study. In our cohort of 60 patients undergoing His-bundle pacing, 10 patients had heart failure with reduced ejection fraction, with a baseline mean LVEF of 41.93 ± 11.33%. After 1 month, LVEF increased to 52.02 ± 11.02%, and after 6 months, mean LVEF improved to 55.80 ± 8.50%. Thus, in the heart failure subgroup, left ventricular systolic function improved by 11.87 ± 10.32% at 6 months after His-bundle pacing. The magnitude of LVEF improvement is comparable to that reported in studies by Ajijola (2017) [20], [104] and Sharma (2021) [104]..

4.3.4. Short-Term Effects on Quality of Life

Studies on His-bundle pacing also require an objective assessment of its effectiveness in improving quality of life after device implantation. Occhietta reported that quality-of-life scores improved after His-bundle pacing, decreasing from 32.5 ± 15.0 before implantation to 16.2 ± 8.7 ($p < 0.05$). Mežnar (2024) showed that SF-36 quality-of-life scores improved with optimization compared with no optimization. Whinnett (2023) conducted a randomized, double-blind, multicenter trial to evaluate atrioventricular (AV) interval optimization after pacemaker implantation and demonstrated that His-bundle pacing improved quality of life as assessed by the Minnesota Living with Heart Failure Questionnaire (MLHFQ) (change −3.7; 95% confidence interval: −7.1 to −0.3; $p = 0.03$). In our study, after His-bundle pacemaker implantation and AV interval optimization, the physical component score of the SF-36 improved by 23.95 ± 23.51 points. In addition to physical quality of life, the SF-36 mental component score also improved by 19.60 ± 21.52 points. Both improvements were statistically significant. These results are consistent with the findings reported by Occhietta, Mežnar, and Whinnett.

CONCLUSION

Our study included 60 patients, of whom 60% were female, with a mean age of 59,03 ± 18,86 years; 95% of patients had atrioventricular block proximal to the His bundle or at the His bundle, 31,7% of patients had a wide QRS, and 16,7% of patients had an ejection fraction below 55%. The study has the following conclusions:

1. The optimal atrioventricular conduction interval determined by invasive cardiac catheterization with dP/dtmax measurement during His-bundle pacing was 115 ± 40,44 ms and during atrial and His-bundle pacing was 169,00 ± 34,03 ms. The optimal atrioventricular conduction interval determined by Doppler echocardiography using mitral valve VTI during His-bundle pacing was 99,66 ± 30,69 and during atrial and His-bundle pacing was 158,66 ± 29,42 ms. The optimal atrioventricular conduction interval determined by Doppler echocardiography using aortic VTI during His-bundle pacing was 103,81 ± 32,30 and during atrial and His-bundle pacing was 163,00 ± 24,92 ms. The optimal atrioventricular conduction interval determined by Doppler echocardiography using ventricular filling time across the mitral valve during His-bundle pacing was 101,33 ± 28,96 and during atrial and His-bundle pacing was 164,00 ± 29,18 ms. All Doppler echocardiographic techniques for atrioventricular conduction interval optimization were positively correlated with the invasive cardiac catheterization method using dP/dtmax and can be used as alternatives for atrioventricular conduction interval optimization when invasive cardiac catheterization cannot be performed.

2. His-bundle pacing is a technique with a success rate of 76,3%. His-bundle pacing narrowed the QRS from 103,86 ± 24,12 ms to 96,06 ± 11,89 ms; this association was statistically significant with p = 0,026. His-bundle pacing also narrowed the QRS better than left bundle branch pacing, with QRS 96,06 ± 11,89 ms in the His-bundle pacing group versus 110,11 ± 10,28 ms in the left bundle branch pacing group, and the difference was statistically significant with p<0,0001. Immediately after implantation and optimization, if only His pacing was applied, left ventricular contractility dP/dtmax increased by 21,39 ± 26,43%; left ventricular systolic pressure increased by 9,81 ± 12,67 mmHg; aortic systolic pressure increased by 5,69 ± 1,61 mmHg; mean aortic pressure increased by 10,01 ± 14,45 mmHg; on echocardiography, mitral VTI increased by 15,61 ± 19,85%, aortic VTI improved by 12,54 ± 19,25%, and ventricular filling time increased by 13,77 ± 23,04%. Immediately after implantation and optimization, if both atrial pacing and His pacing were applied, left ventricular contractility dP/dtmax increased by 29,32 ± 32,59%; left ventricular systolic pressure increased by 9,00 ± 13,92 mmHg; aortic systolic pressure increased by 4,88 ± 12,33 mmHg; mean aortic pressure increased by 13,08 ± 12,56 mmHg;

on echocardiography, mitral VTI increased by 8,30 ± 16,16%, aortic VTI increased by 6,24 ± 16,86%, and ventricular filling time improved by 3,31 ± 14,66%. After 6 months of follow-up, patients who underwent His-bundle pacing and had the optimal atrioventricular conduction interval programmed according to invasive cardiac catheterization with dP/dtmax showed a trend toward better improvement in cardiac function compared with before His-bundle pacing; however, the improvement was not statistically significant; nevertheless, in the subgroup with ejection fraction < 55%, after 6 months of His-bundle pacing, ejection fraction improved from 41,93 ± 11,33% to 55,80 ± 8,50%. His pacing and atrioventricular conduction interval optimization using invasive cardiac catheterization improved physical quality of life by 23,95 ± 23,51 points and mental quality of life by 19,6 ± 21,52. The common MACE complications in His-bundle pacing were mainly due to His lead loss of capture and most often occurred within the first week. The rate of His lead loss of capture within the first week was 4,22%. The complication rate after 6 months of follow-up was 5,6%. The main reasons for procedural failure were inability to locate the His position and a high His threshold > 2 V. In addition, threshold increase or loss of capture after sheath removal was also a common cause..

RECOMMENDATIONS

For patients expected to require ventricular pacing for more than 20% of the time, His-bundle pacing should be considered because it can correct conduction abnormalities and narrow the QRS and QT intervals compared with intrinsic rhythm and right ventricular pacing. His-bundle pacing also achieves greater QRS narrowing than left bundle branch pacing.

After His-bundle pacing implantation, atrioventricular (AV) conduction interval optimization using invasive cardiac catheterization is recommended. If invasive catheterization for AV interval optimization is not feasible, Doppler echocardiography–guided AV interval optimization using mitral inflow VTI, aortic valve VTI, or ventricular filling time may be used as alternative approaches to enhance therapeutic effectiveness.

In situations where AV interval optimization cannot be performed using either invasive catheterization or Doppler echocardiography, our findings suggest that AVs may be temporarily programmed to 115 ms and AVp to 169 ms

LIST OF PUBLISHED RESEARCH WORKS RELATED TO THE DISSERTATION

1. Kiều Ngọc Dũng, Nguyễn Tri Thức, Hoàng Anh Tiến (2023). "Tối ưu hóa khoảng dẫn truyền nhĩ thất ở bệnh nhân đặt máy tạo nhịp hệ thống dẫn truyền". *Tạp Chí Y học Việt Nam,* 529(1). https://doi.org/10.51298/vmj.v529i1.6294
2. Kiều Ngọc Dũng, Hoàng Anh Tiến, Nguyễn Tri Thức (2023) "Tối ưu hóa khoảng dẫn truyền nhĩ thất ở bệnh nhân đặt máy tạo nhịp bó His". Tạp chí Y Dược Huế - Số 7, tập 13, tháng 12/2023. Tr.177-182. https://www.huejmp.vn/index.php/journal/article/view/233/227
3. Nguyễn Tri Thức, Kiều Ngọc Dũng, Hoàng Anh Tiến, Nguyễn Cửu Long (2023). "Các kỹ thuật tối ưu hóa khoảng dẫn truyền nhĩ thất ở bệnh nhân đặt máy tái đồng bộ tim". *Tạp Chí Y học Việt Nam*, 529(2). https://doi.org/10.51298/vmj.v529i2.6484
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