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# MAXIMUM LV DP/DT$_{MAX}$ ACHIEVED WITH MULTIPOINT™ PACING AS MEASURED BY NON-INVASIVE MEANS IN A TERMINAL HEART FAILURE PATIENT

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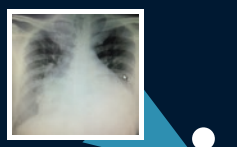
**MULTIPOINT™ PACING CASE STUDY**

**HEMODYNAMIC** CHANGES IN A PATIENT UNDERGOING CARDIAC RESYNCHRONIZATION THERAPY



56 YEAR OLD MALE WITH MULTIPLE COMORBIDITIES

NYHA CLASS IV

LVDD/SD 9.0/8.7 CM

EF: 8%

PRODUCT IMPLANTED QUADRA ASSURA MP™ CRT-D

ONE MONTH

EF: 15%

MULTIPOINT™ PACING WAS TURNED ON

SIX MONTHS

NYHA CLASS II

LVDD/SD 8.3/7.4 CM

EF: 24%

SIX-MONTH POST-IMPLANT WITH MULTIPOINT™ PACING THERAPY

## PATIENT HISTORY

A 56-year-old man with advanced heart failure was initially referred for consideration of heart transplantation. He presented with repeated heart failure hospitalization since the beginning of 2014 and continued to deteriorate despite best-tolerated optimal medical therapy (NYHA Class IV ambulatory).

The patient's detailed medical history revealed multiple co-morbidities, including a history of Crohn's disease and Behcet syndrome with severe aortitis. He has a medical history of Crohn's disease and Behçet syndrome with severe aortitis. He underwent prosthetic aortic valve replacement (AVR) and mitral valvuloplasty in 2006 for severe aortic and mitral regurgitation. Due to recurrent infective endocarditis, he required lifelong clindamycin treatment. Other significant co-morbidities included renal cell carcinoma with left nephrectomy performed in 2005. MRI of the brain showed multiple old infarcts.

Taking into account the above medical history, he was considered neither a suitable candidate for heart transplant nor an implantable left ventricular assist device (LVAD) recipient. After much detailed discussions, cardiac resynchronization therapy (CRT) was offered as a last resort for him and a special effort was made to ensure the best possible CRT programming and optimization for this desperate patient.

## PROCEDURE

The patient's baseline characteristics included the following:

1. ECG: Sinus rhythm with LBBB pattern (QRS duration 225 ms)
2. Echocardiography: Markedly dilated left ventricle (LV) with globally impaired contraction (LVdd/sd was 9.0/8.7 cm, ejection fraction 8%), moderate mitral regurgitation, AV prosthesis functioning with no paravalvular leakage seen

The patient underwent successful CRT-D implantation (Quadra Assura MP™ CRT-D, Abbott) with LV quadripolar lead (Quartet™ Quadripolar LV Lead 1458Q/86, Abbott) positioned in coronary sinus lateral branch in January 2015 (Figures 1a and 1b).

Acute direct invasive hemodynamic measurements of LV $dP/dt_{max}$ could not be performed during the procedure due to the presence of mechanical aortic valve prosthesis. Instead, both acute data during implantation and subsequent chronic hemodynamic data were collected by using Nexfin™ hemodynamic monitoring system (Edwards Lifesciences) (Figure 2). The result of the $dP/dt_{max}$ by Nexfin system measured during implantation is shown in Table 1.

**Figure 1a.** Retrograde coronary sinus venogram (LAO view) delineating CS branches. The metallic aortic valve prosthesis and mitral valvuloplasty ring could be clearly visualized.

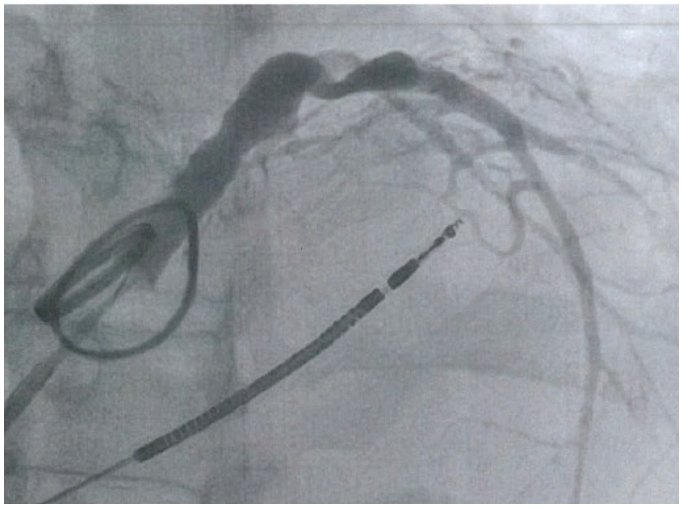
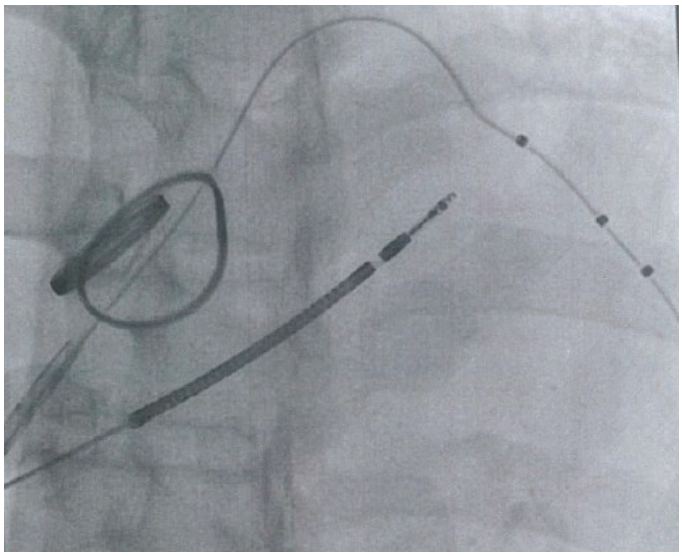


**Figure 1b.** Position of LV Quadripolar lead in CS posterolateral branch



Other additional features utilized for further optimization of device programming (all from Abbott) are shown in Figure 3:

1. QuickOpt™ timing cycle optimization
2. VectSelect™ programmable LV pulse configuration
3. RV-LV conduction time measurement
4. DeFT Response™ technology

In view of markedly dilated LV, MultiPoint™ Pacing (Abbott) was not turned on until one month follow-up when the final position of the LV lead was fixed and stabilized. We repeated the echocardiogram at one month post-conventional biventricular pacing, three and six months after MultiPoint™ Pacing was programmed at best selected configurations as guided by $dP/dt_{max}$.

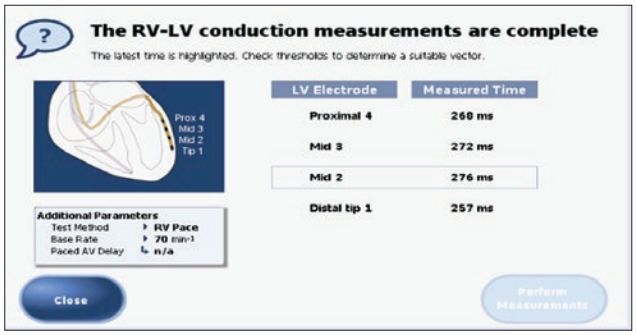
A simple, noninvasive approach to monitoring key hemodynamic parameters.

- Stroke Volume (SV)
- Stroke Volume Variation (SVV)
- Cardiac Output (CO)
- Systemic Vascular Resistance (SVR)
- Continuous Blood Pressure (cBP)

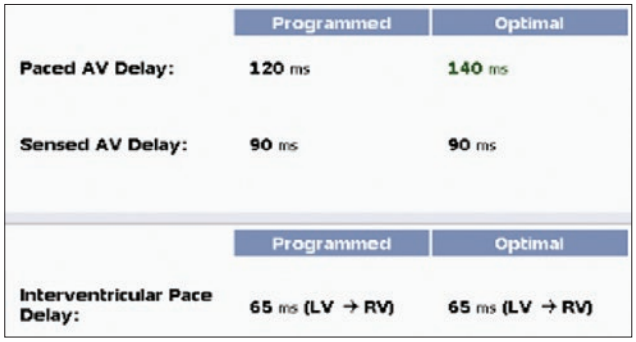
Cross-section of cuff application.

To accurately mirror arterial line output, real-time finger pressure measurement is performed 1000 times per second utilizing the volume clamp method.

**Figure 3.** Measurement of RV-LV conduction and QuickOpt™ optimization for recommendations of MultiPoint™ Pacing setting




Measurement of RV-LV conduction delay try to find out the longest conduction time and shortest conduction time.




QuickOpt™ optimization measurement

**Table 1.** Results of LV $dP/dt_{max}$ measurement by Nexfin™ system during implant

| Types of measurement | Mode of Pacing | $dP/dt_{max}$ Measurement |
|---|---|---|
| Baseline | ApVs | 856 |
| RV pacing only | ApRVp | 891 |
| LV pacing only<br>LV pacing D1 to M2 | ApLVp | 1107 |
| Bi-V pacing with nominal setting<br>LV: D1 to M2<br>PAV: 140 ms/SAV:<br>90 ms/Simultaneously | ApBiVp | 1133 |
| Bi-V pacing with<br>QuickOpt™ optimization<br>LV: D1 to M2<br>PAV 140 ms/SAV 90 ms/<br>LV first 65 ms | ApBiVp | 1126 |

**Table 2.** Measurement of $dP/dt_{max}$ by Nexfin™ system one-month follow-up

| Mode of pacing | | | dP/dt measurement (mmHg) |
|---|---|---|---|
| MultiPoint™ Pacing | LV1: M2-P4<br>LV2: M3-M2 | LV1 - LV2 Delay: 5 ms<br>LV2 - RV Delay: 30 ms | 1120 |
| | | LV1 - LV2 Delay: 10 ms<br>LV2 - RV Delay: 25 ms | 1124 |
| | | LV1 - LV2 Delay: 15 ms<br>LV2 - RV Delay: 20 ms | 1161 |
| | | LV1 - LV2 Delay: 20 ms<br>LV2 - RV Delay: 15 ms | 1209 |
| | | LV1 - LV2 Delay: 25 ms<br>LV2 - RV Delay: 10 ms | 1262 |
| | | LV1 - LV2 Delay: 30 ms<br>LV2 - RV Delay: 5 ms | 1273 |

## RESULTS

The patient was discharged home with CRT pacing under conventional biventricular pacing configuration, namely PAV 140 ms/SAV 90 ms with LV first 65 ms by QuickOpt™ optimization, and quadripolar LV lead vector of D1-P4 since this configuration had the lowest capture threshold without phrenic nerve stimulation. His ECGs at baseline and post CRT implantation were showed in Figures 4a and 4b.

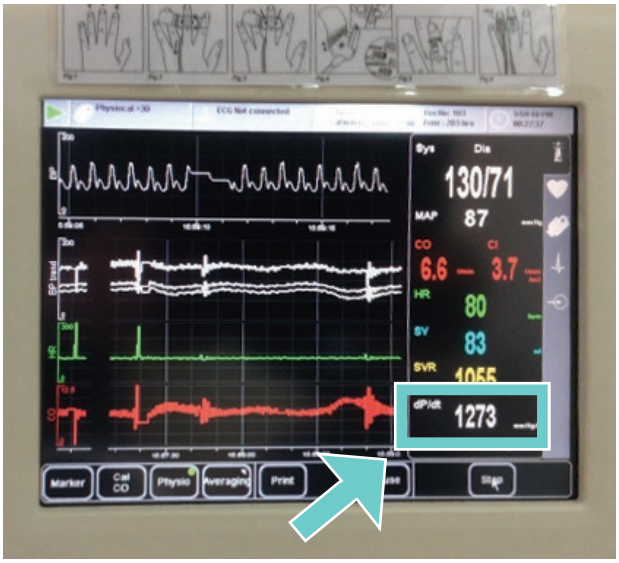
**Figure 4a.** ECG at baseline with LBBB pattern (QRS duration: 225 ms)

**Figure 4b.** ECG at post-CRT-D implantation

The patient returned at one month post-implantation and was reassessed with an echocardiogram (LVdd/Sd 9.3/8.6cm, EF 15%) and underwent repeat cardiac resynchronization therapy optimization using Nexfin™ continuous hemodynamic monitoring system as guidance (Figures 5a and 5b). Due to non-invasiveness of Nexfin™ system, we devised a more detailed study by testing various combinations of MultiPoint™ Pacing programming in order to identify the best cardiac output with maximum $dP/dt_{max}$. In this case, the best MultiPoint™ Pacing configuration was LV1(M2-P4) to LV2(M3-M2): 30 ms and LV2(M3-M2) to RV 5 ms as shown in Table 2. His latest echocardiogram performed six months post-implant showed significant remodeling effects (LVdd/sd 8.3/7.4 cm, EF 24%). A comparison of his chest X-rays before CRT-D implantation and at six months was shown in Figures 6a and 6b showing evidence of significant reduction in cardiomegaly. Clinically, the patient has significant improvement in exercise tolerance (NYHA Class II) during subsequent follow-ups.

**Figure 5a.** Patient undergoing detailed study with various MultiPoint™ Pacing programming combinations.

**Figure 5b.** Best $dP/dt_{max}$ 1273 mmHg (arrow) indicated with best optimal MultiPoint™ Pacing setting



## DISCUSSION

Cardiac resynchronization therapy has been shown to improve exercise capacity and quality of life and to reduce heart failure hospitalizations and mortality in patients with NYHA Class III and IV heart failure.[1,2] In randomized studies, the number of NYHA Class IV heart failure patients enrolled has been very low. Many NYHA Class IV patients are still considered unsuitable for survival studies and have been systematically excluded from clinical trials because of the expectation of a much shortened lifespan. The COMPANION trial's sub-analysis of NYHA Class IV patients demonstrated that CRT-P and CRT-D improve only the combined endpoint of time to all-cause mortality and hospitalizations in ambulatory NYHA Class IV patients but could not show a benefit on survival.[3-5]

In reality, the line between NYHA classes is not distinct and determination of disease severity in heart failure requires a wide range of clinical, biochemical and functional parameters. As a result, universally accepted and definable measures are still lacking. Furthermore, many of these patients are ambulatory but require repeated hospitalizations with resource-consuming treatments, and neither heart transplant nor implantation of assist devices are appropriate treatment for them. The patient reported here illustrated the actual reality case in which carefully titrated MultiPoint™ Pacing therapy allowed significant reverse remodeling in an otherwise desperate patient with end-stage heart failure, which we encountered other than those patients included and reported in large randomized clinical survival studies.

Invasive acute hemodynamic response by measuring $dP/dt_{max}$ to guide LV lead implantation predicts chronic remodeling in patients undergoing CRT.[6] This was contraindicated in this patient with mechanical aortic valve prosthesis and thus we resorted to use an alternative non-invasive hemodynamic monitor Nexfin™ system as a guide to clinical decisions for guiding MultiPoint Pacing therapy for this patient. In fact, due to its non-invasive nature, future refinement of MultiPoint Pacing programming during short- and long-term follow-ups becomes an added bonus.

The measurement of cardiac output (CO) has been traditionally limited to critically ill patients in the intensive care unit. However, with an increasing number of heart failure patients undergoing device therapy such as CRT, goal-directed therapy of maximizing CO and $dP/dt_{max}$ values in acute setting and long-term management guided by non-invasive manner is desirable. The recently introduced Nexfin™ monitoring system is a completely non-invasive system requiring only the use of pneumatic finger cuff, without the insertion of any intravascular lines. It consists of a model-based method that provides beat-to-beat measurement of CO by analysis of the non-invasive finger arterial blood pressure trace, which is measured continuously by the use of an inflatable finger cuff. Stroke volume is determined by dividing the pulsatile systolic area of each beat by impedance, which is estimated by the device based on patient characteristics.

Numerous studies have been published validating this technique for monitoring blood pressures when compared to invasive monitoring.[7,8] Although this was associated with some conflicting results as to its potential usefulness with recent studies, it showed promising results in regards to its ability to trend when compared to pulmonary artery catheter values,[7,9] transthoracic echocardiography and esophageal Doppler.[10] Furthermore, we propose that CO and $dP/dt_{max}$ data obtained by a less invasive technique, even if slightly less accurate, may be preferable if it can be obtained more rapidly and conveniently, and allows tracking and titrating the short-term and long-term effects of MultiPoint™ Pacing in patients with advanced heart failure implanted with CRT.

## CONCLUSION

In addition to a novel and innovative approach at the optimization of therapy using the Nexfin system, this case study reflects a significant clinical improvement with MultiPoint Pacing in the conversion of a hemodynamically unstable NYHA class IV heart failure with multiple comorbidities, who was previously rejected for advanced heart failure treatments.

**Figure 6a.** X-ray pre-implant

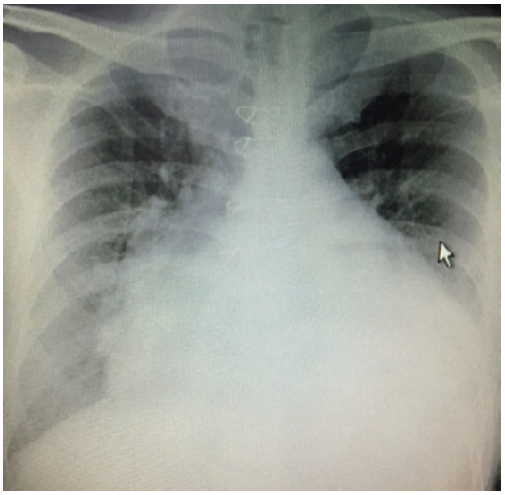
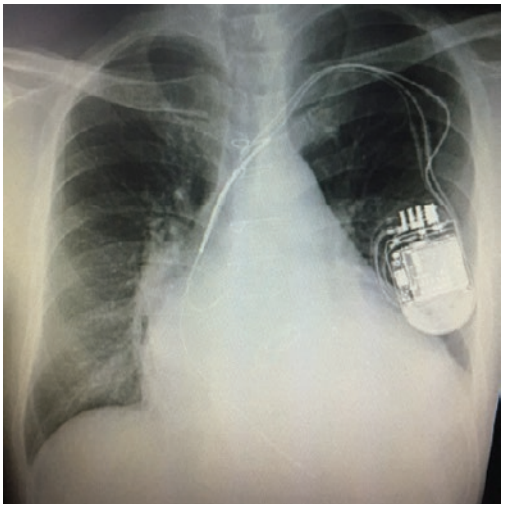


**Figure 6b.** Six-month post-implant with MultiPoint™ Pacing therapy



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