Cardiac Resynchronization Therapy Malfunction

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Introduction: CRT

- Cardiac resynchronization therapy (CRT) as a routine approach in the management of patients with heart failure, spread from few investigational centers to smaller units that may have started implementing CRT only recently.

- Careful medical management and monitoring of the CRT patients before, during but also after implantation would increase the efficacy of CRT and decrease the complications rates.
In-hospital monitoring

- Confirmation of biventricular capture has to be assessed daily by analyzing **the surface ECG** and comparing it with the ECG templates recorded at the time of implant.

- **Atrial and ventricular threshold data** for both pacing and sensing have to be recorded before hospital discharge, providing a reference for further follow-up.

- Finally a **chest X-ray** is usually performed as a reference for the next follow-up.
Causes of CRT malfunction

Device related

Arrhythmias related

Patient related
Device-related complications can be further classified into complications caused by

- **Loss of Biventricular capture**
- **Inadequate tachycardia** sensing or therapy.

1. **Pacemaker-mediated tachycardia** between the two ventricular electrodes

2. **Double-sensing of RV and LV activation** leading to inappropriate Sensing of ventricular tachycardia and thus delivery of inadequate shocks
When to suspect loss of biventricular capture?

- The most frequent situation is a **hemodynamic deterioration** occurring after a period of significant clinical improvement.

- The loss of biventricular capture may be responsible in some cases of **acute** or **sub-acute pulmonary edema**.

- The loss of biventricular capture may be asymptomatic and diagnosed during a scheduled follow-up with the analysis of QRS complexes **on surface ECG**, or it may be suspected from **data from the device**.
Causes of loss of permanent or temporary biventricular pacing

- Left ventricular lead dislodgement
- Increase in LV or RV pacing thresholds
  - Right ventricular lead dislodgement
  - Non-optimal AV delay
  - Atrial tachyarrhythmias with rapid ventricular rate
  - Low maximal tracking rate
  - Frequent ventricular premature beats
  - Atrial undersensing
  - T Wave oversensing
  - Far-field atrial sensing
  - Ventricular double counting
The first cause of permanent loss of Biventricular capture is the dislodgement of the LV lead. A LV lead dislodgement is reported in 2–10% of cases.

LV lead dislodgement may require a **re-operation**, especially if the pacing threshold becomes too high. If the increase of LV pacing threshold is moderate an **increase in the LV output** may be a solution to avoid a re-operation with the risk of complications such as infection.

The repositioning of the LV lead should be discussed when the pacemaker is replaced in case of battery depletion for example.

In some cases, the chest X-ray does not show any significant dislodgement, suggesting

- a so-called **micro-dislodgement**
- an **exit block**
- an **inhibition of ventricular capture** due to a tuning problem
Chest X-ray of a patient implanted with a biventricular defibrillator. The atrial lead is placed in the right appendage, the RV lead in the mid interventricular septum and the LV lead into the lateral vein of the coronary sinus.

Anteroposterior chest X-ray in the same patient 2 days later showing a dislodgement of the LV lead now located into the body of the coronary sinus.
A: The target site of left ventricle lead is just in posterolateral vein.
B: At follow-up, left ventricle lead dislodged to the coronary sinus.
Complications

- A dislodged LV lead may potentially prolapse into the RV and cause **ventricular arrhythmias**, or induce **atrial fibrillation** if it is floating in the right atrium (RA).

- Moreover, due to the loss of synchronization, **cardiac decompensation** may be precipitated.
Fixation mechanisms to secure LV leads

Coronary sinus leads with different fixation mechanisms.

(a) **Corox lead** (BIOTRONIK, Berlin, Germany), using a helix for passive fixation.
(b) **Attain StarFix lead** (Medtronic, Minneapolis, USA) with deployable lobes.
(c) **Endotak Reliance lead** (Guidant, St Paul, USA) with active (screw) or passive (anchor) fixation.
(d) **Aescula lead** (St Jude Medical, St Paul, USA), with a helix for passive fixation.
Stenting for recurrent dislodgment of the left ventricular lead. This approach is not recommended as routine.
ECG DIAGNOSIS FOR CRT MALFUNCTION
ECG diagnosis for CRT malfunction

Golden Rule

During the implantation procedure a 12-lead ECG should be recorded to identify the ECG pattern of intrinsic rhythm, RV pacing, LV pacing, and biventricular pacing.
Definition of Axis

- Axis describes the net direction of ventricular depolarization
Theory

RV Pacing  LV Pacing  BV Pacing
ECG diagnosis for CRT malfunction

During pacing the mean frontal plane QRS axis reflects the site of the pacing
ECG QRS Patterns during RV pacing

**RV APICAL PACING**

The frontal plane axis is usually left superior. It may also be in the right superior quadrant, where it causes leads I, II & III to be negative and lead aVR to show the largest positive deflection.

A typical LBBB pattern in the left precordial leads may not be present and all leads show a QS pattern.

The left precordial leads may show a dominant R wave.

**RV OUTFLOW TRACT PACING**

The frontal plane axis is normal i.e. as for normally conducted beats. But as the lead moves towards the pulmonary valve, the axis becomes deviated to the right. A qR pattern can occur only in leads I & aVL.
The mean frontal plane axis of the paced beat is directed to the right lower quadrant (right axis deviation), there is a characteristic tall R wave in lead V1 to at least V3 and often further into the left precordial leads.
Experience with the VIGOR CHF demonstrates the relationship between BV, RV, and LV axes and their distribution.

Although the patient population axes are variable, for a given individual, the BV axis is always superior and in between the RV and LV pacing axes.
Leads I and III Best Show Changes

Diagram illustrating the vector directions for BV to RV and BV to LV.
Experience with the VIGOR CHF study confirms that the axis shift from BV to RV pacing is reflected in increasing positivity of the QRS in Lead I. Although the axes may start and end in different places, the shift is always towards the patient’s left.
EXPECTED CHANGES IN ECG MORPHOLOGY
Think Positive

BV to RV Pacing in Lead I

BV to LV Pacing in Lead III
Think Positive

- Perform threshold test while simultaneously monitoring Leads I and III

- Both lead I and III should be negative

- If the amplitude of Lead I shows increasing positivity, then the patient has gone from BV pacing to RV pacing

- If the amplitude of Lead III shows increasing positivity, then the patient has gone from BV pacing to LV pacing
ECG QRS Patterns during BiV Pacing

Biventricular pacing (RV + LV) produces a right superior axis as a result of fusion of RV and LV electrical axes.

A qR or Qr complex in lead I is rare in uncomplicated RV apical pacing. It is present in 90% of cases of biventricular pacing.

In biventricular pacing, loss of the q or Q wave in lead I is 100% predictive of loss of LV capture.
Twelve-lead ECG with biventricular pacing.

Twelve lead ECG in the same patient one month later showing the loss of LV capture associated with hemodynamic deterioration after an initial hemodynamic improvement.
In CRT patients a permanent or paroxysmal diaphragmatic stimulation may occur in up to 5–10% of patients, resulting in major discomfort for the patients.

This complication is related to the anatomical vicinity of the left phrenic nerve and the LV pacing site.

Especially when the LV lead is implanted into a posterior or posterolateral vein.
Phrenic nerve stimulation

**Prevention**

During LV lead implantation phrenic nerve stimulation has to

- be assessed using a high voltage output at 10 V

- deep breath maneuvers.

When phrenic nerve stimulation occurs during LV lead implantation, it is recommended to consider another LV pacing site without phrenic nerve stimulation.
Phrenic nerve stimulation

Intra-operative chest X-ray an LV lead inserted into the posterolateral vein of the coronary sinus. A diaphragmatic stimulation occurred even with low LV output (1 V). The LV pacing threshold was measured at 0.75 V with a pulse width of 0.5 ms. With a more proximal position of the LV lead in the posterolateral vein, diaphragmatic stimulation disappeared even at high output (10 V) with an acceptable LV pacing threshold at 1.25 V.
Phrenic nerve stimulation

Management

- The occurrence of phrenic nerve stimulation early may signal an LV lead migration. The assessment of the LV capture threshold and of the phrenic nerve stimulation thresholds has to be performed.

- If the LV capture threshold falls far below the phrenic nerve stimulation threshold, the reduction in LV pacing amplitude below the phrenic nerve stimulation threshold may simply solve the problem.
Recent bipolar pacing LV leads with the benefit of reprogramming of the LV lead pacing in various configurations might be useful to decrease phrenic nerve stimulation without the need of LV lead replacement.
ARRHYTHMIA RELATED CRT MALFUNCTION
Atrial fibrillation is common in patients with advanced heart failure.

It may lead to precipitation of acute heart failure decompensation caused by:

- Loss of the **atrial contribution** to stroke volume
- **Impaired diastolic filling if rapid** conduction to the ventricles occurs
- The irregularity in itself leading to **variation in ventricular filling and contractility**.
- **Loss of the atrial-sensed event triggering the resynchronizing biventricular stimulus.**
paroxysmal AF

- Mode-switching activation may avoid a rapid ventricular rate.

- New features are available in the most recent devices to increase the percentage of ventricular pacing with little or no increase in the daily mean heart rate and so to promote delivery of CRT during AF/AT episode.
Mode switch of the Medtronic InSync Sentry. (1) An atrial tachyarrhythmia starts, causing rapid ventricular pacing in response. (2) The onset of atrial tachyarrhythmia occurs, and mode switch changes the pacing mode to DDIR. (3) The device gradually changes from the faster ventricular pacing rate to the slower sensor-indicated rate.
Permanent AF

- **Rate control and Anticoagulation** in patients with permanent atrial fibrillation without spontaneous or radiofrequency-induced AV block

- **Radiofrequency AV node ablation** may be recommended to optimize the CRT delivery
Remote Monitoring

A recent System of remote CRT Monitoring has many advantages

- May replace some in-clinic follow-ups
- Early detection of device malfunction
- Avoid the patient tendency to neglect follow-ups
- Reduce Follow-up costs
Remote Monitoring

- Medtronic CareLink Network
- St. Jude Merlin@Home
- Biotronik CardioMessenger
- Boston Scientific LATITUDE System
Thank You