Understanding Hemodynamics of Pacing Modes

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Hemodynamic Optimization and Pacing

→ Optimization of systolic performance
  - Optimization of contractility
    → pacing site
  - Optimization of synchronization of contraction
    → pacing site, no. of pacing sites

→ Optimization of diastolic performance
  - Optimization of diastolic filling time
    → AV timing
    → VV timing
  - Optimization of atrial contribution
    → Atrial pacing site
    → Pacing mode

→ Optimization of heart rate
  → Rate-adaptive pacing
Quantification of Hemodynamics in Pacing

• Echocardiography
  - left ventricular ejection fraction
  - cardiac output, stroke volume
  - diastolic filling time
  - tissue doppler derived measurements

• Catheterization
  - cardiac output
  - pulmonary capillary wedge pressure (PCWP)
  - contractility (dP/dt)
  - pulse pressure

• Noninvasive blood pressure measurement
  - finger plethysmography
Hemodynamics of Pacing Mode

→ Pacemaker syndrome
Optimization of Pacing Mode
Hemodynamics in Pacemaker Syndrome

Massive V wave (PCWP) due to VVI pacing with 1:1 retrograde conduction

Lamas, Circulation 2004;109:443-51
Jugular and Carotis Pulse

- Exaggerated A wave
- Shortened LV ejection time

Bergbauer, Herzschrittmacher 1985;5:126-30
Jugular and Carotis Pulse

VVI, 100 bpm with 2:1 retrograde conduction

Bergbauer, Herzschrittmacher 1985;5:126-30
Hemodynamics: Pacemaker Syndrome

z: retrograde flow into the PVs ("cannon z waves")

Stierle, PACE 1995;18:2028-34
Hemodynamics: Pacemaker Syndrome

Retrograde flow into the PVs even in the absence of retrograde conduction

Stierle, PACE 1995;18:2028-34
Atypical Pacemaker Syndromes

AAIR pacing with (extremely) long intrinsic AV conduction (stimulus-Q: 480 ms)
Hemodynamics of Pacing Mode

→ Pacemaker syndrome

→ Atrial pacing
Atrial Pacing

Intrinsic P wave

Paced P wave
Hemodynamics

Atrial Pacing: RAA

SVC

RAA

MV

TV

IVC

LV Contraction

MV Closure

E

A

E

A

LV Contraction MV Closure
Atrial Pacing: Septal

- SVC
- SAN
- IVC
- MV
- TV
- Bachmann’s bundle
- LV Contraction
- MV Closure
Hemodynamics of Pacing Mode

→ Pacemaker syndrome

→ Atrial pacing

→ Right ventricular pacing
PV Loops for Evaluation of Intra-LV Synchrony

- multi-electrode conductance catheter positioned in LV retrograde via aorta
- “square” loop is footprint of synchrony

Lieberman, Circulation 2004;11:III-606
RVA Pacing-Mediated LV Dyssynchrony

Baseline: all LV segments have relative square loops = intra LV Synchrony

DDD-RVA: multiple LV segments abnormal loops = intra LV dyssynchrony*

Lieberman, Hettrick, Eastman Circulation 2004;11:III-606
RVA Pacing Promoting LV Intra-ventricular Dyssynchrony

RV Septal pacing Promoting intra-ventricular LV synchrony

RVA Pacing

NSR

RV Septal Pacing
Hemodynamics of Pacing Mode

→ Pacemaker syndrome
→ Atrial pacing
→ Right ventricular pacing
→ AV delay optimization
Optimal AV Delay

LV Contraction
MV Closure
Optimal AV Delay

Long Diastolic MR

Short
Diastolic Filling Time

AV Dyssynchrony:
LVFT < 40% of the cardiac cycle

Cazeau Heart 2000; 84;579-581
Interventricular Dyssynchrony

$IVD = LPEP - RPEP > 40 \text{ ms}$

Aortic pre-ejection delay $>140 \text{ ms}$

Cazeau Heart 2000; 84;579-581
Contraction/Filling Overlap

LPEP > 140 ms

Diastolic Contraction

Overlap contraction-filling

• part of ventricular contraction is not utilised toward ejection

• filling is impeded by persistent shortening along the long axis

Temporal interventricular dyssynchrony
LPEP > 140 ms or overlap contraction/filling

Cazeau Heart 2000; 84;579-581
Hemodynamics

Echo-Parameter for AV Delay Optimization in CRT

diastolic filling time (E-A duration)

Mitral inflow
E-A VTI

LVOT VTI

Ritter’s formula
AV short + ([AV long + QA long] – [AV short + QA short])

Jansen, Am J Cardiol 2006;97:552-557
Isovolemic Contraction in CRT

\[ P_1 - P_2 = P_2 - P_3 \]

QRS = 165 ms

QRS = 125 ms

CO = 3.8 l/min

CO = 4.1 l/min

CO = 4.5 l/min

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