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**

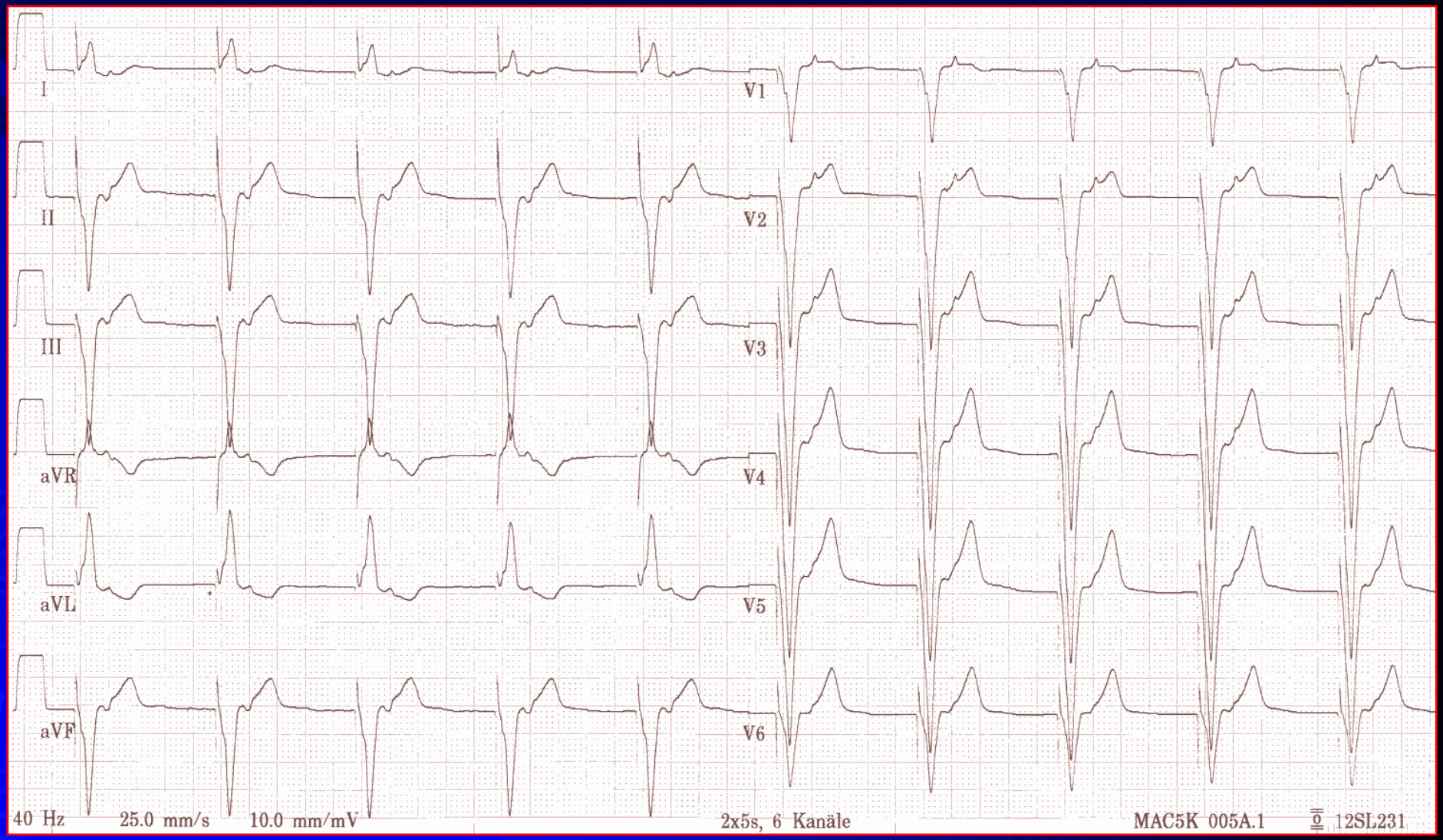
Quantification of Hemodynamics in Pacing

- 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

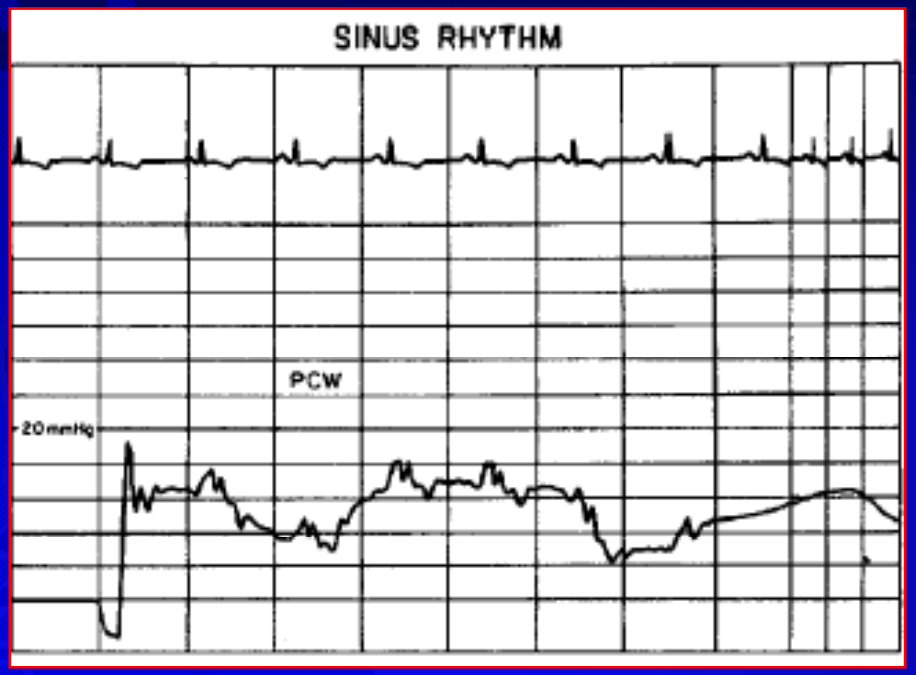
Hemodynamics of Pacing Mode

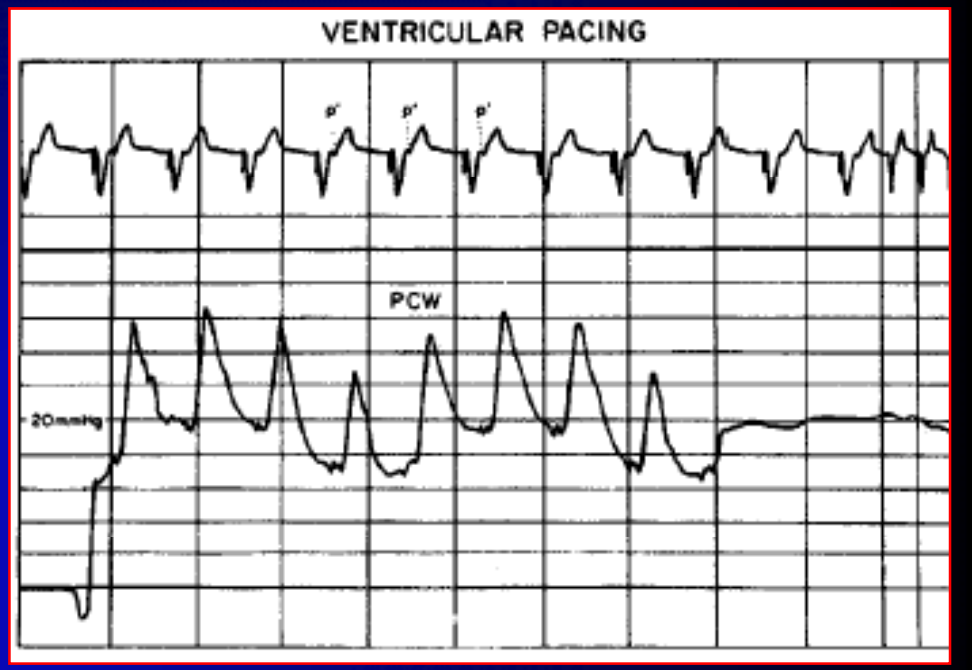
→ Pacemaker syndrome

Optimization of Pacing Mode



Hemodynamics in Pacemaker Syndrome





Massive V wave (PCWP) due to VVI pacing with 1:1 retro-grade conduction

Lamas, Circulation 2004;109:443-51

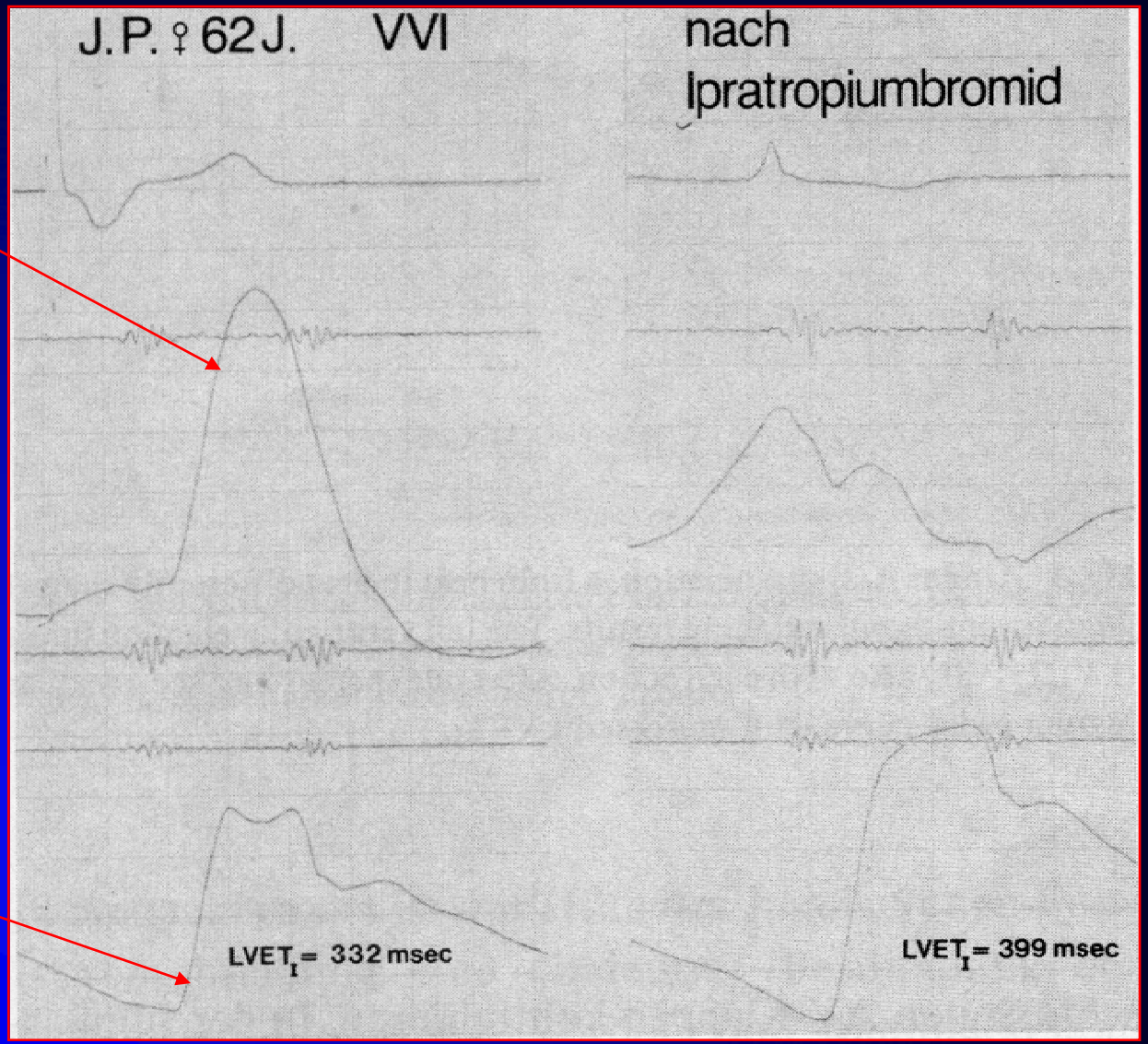
Jugular and Carotis Pulse

Exaggerated A wave

JV Pulse

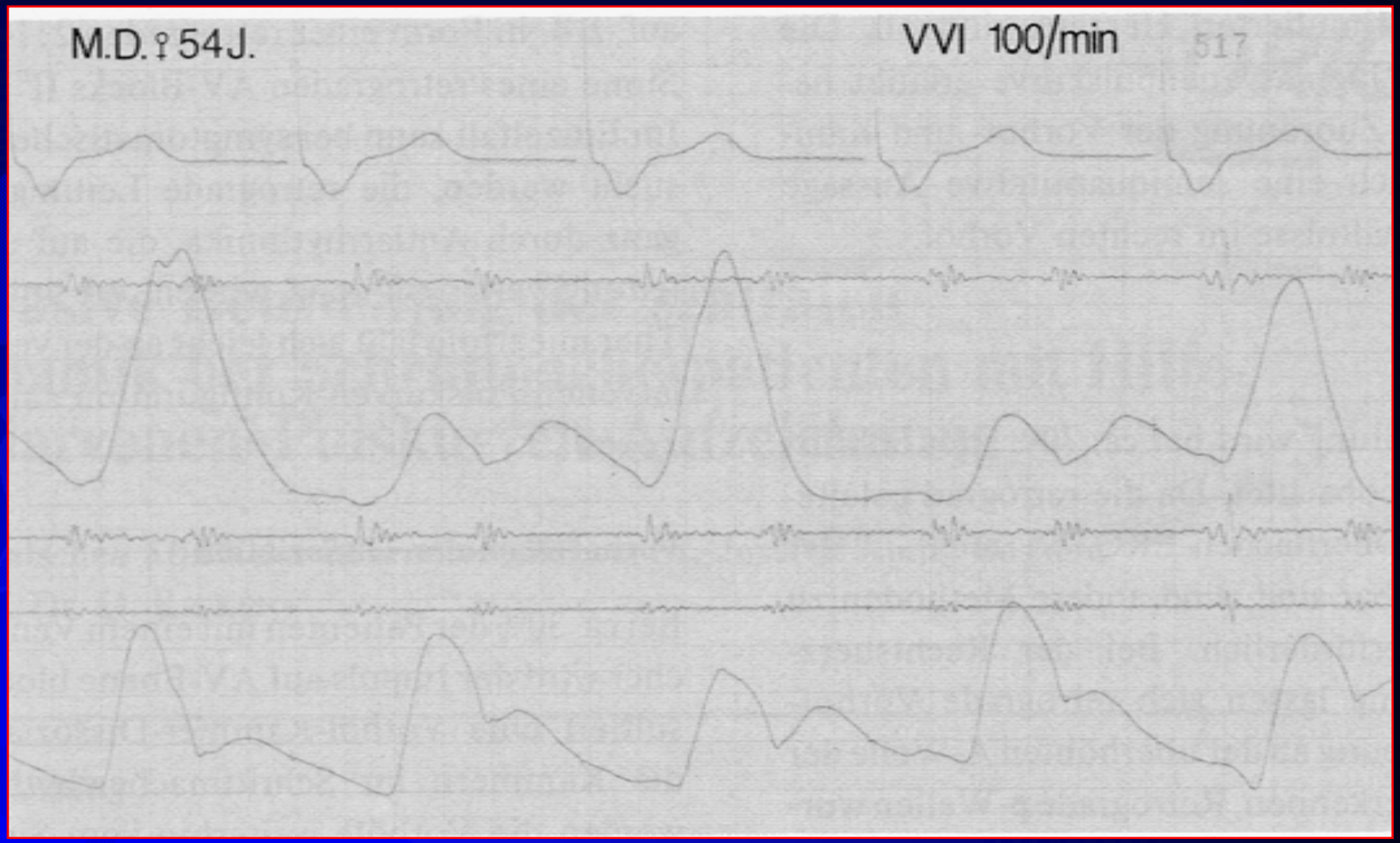
Shortened LV ejection time

Carotis Pulse



Bergbauer, Herzschrittmacher 1985;5:126-30

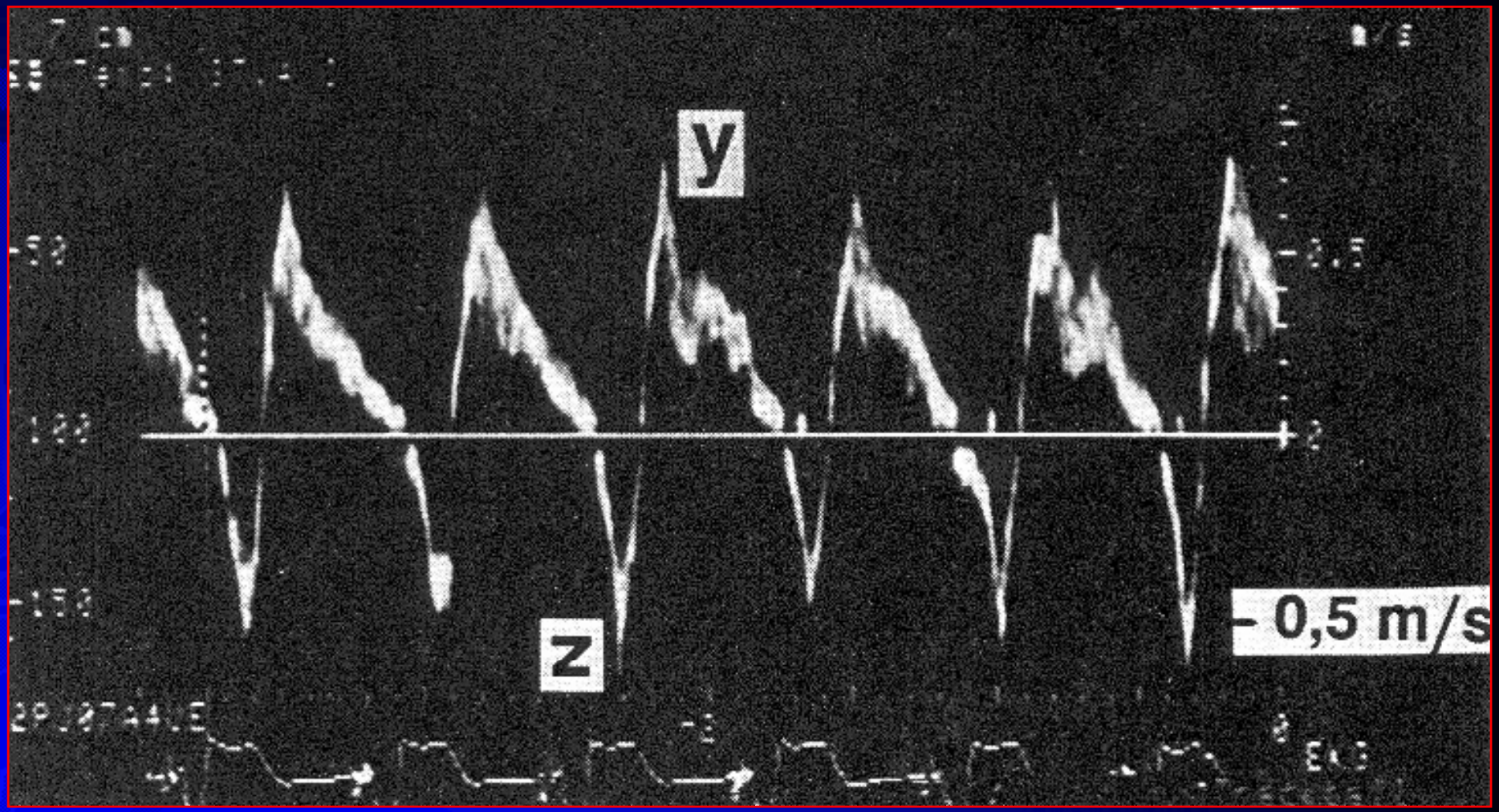
Jugular and Carotis Pulse



VVI, 100 bpm with 2:1 retrograde conduction

Bergbauer, Herzschrittmacher 1985;5:126-30

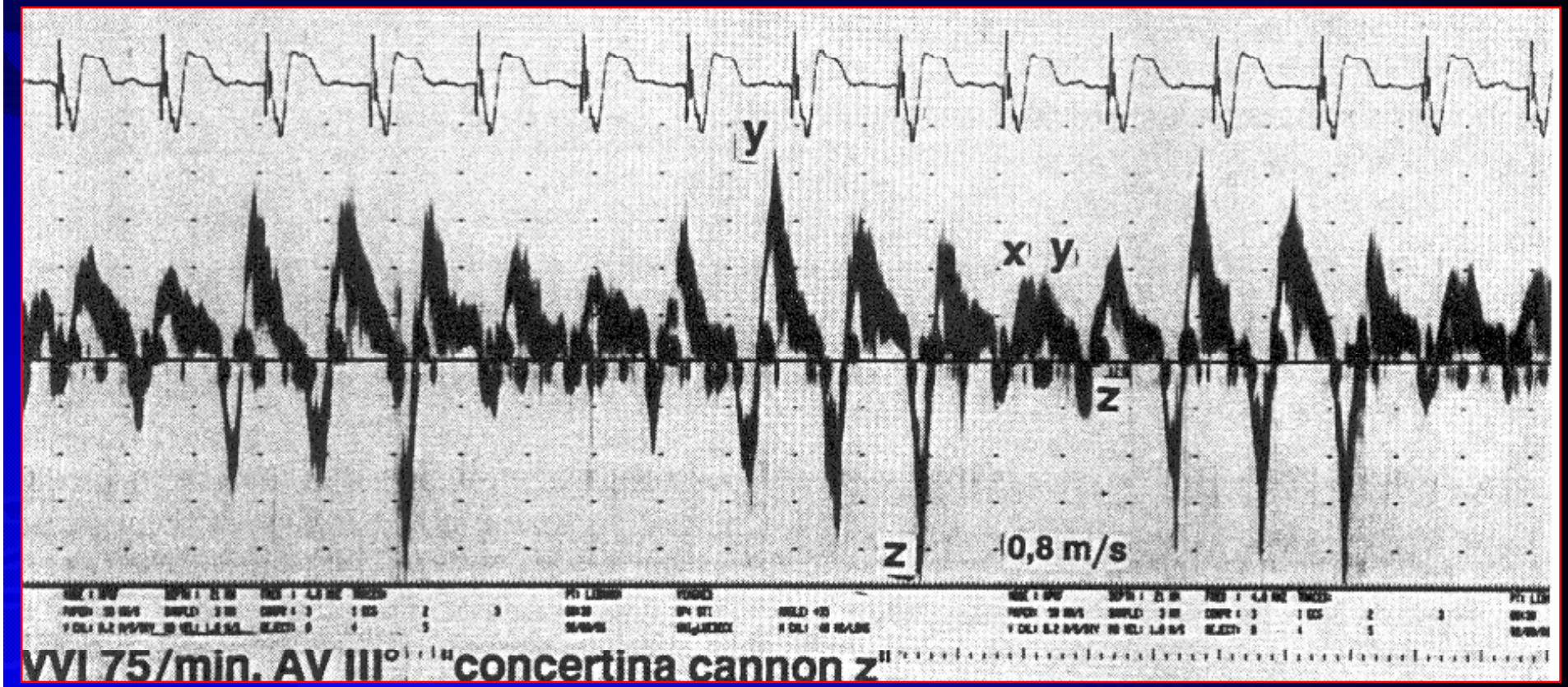
Hemodynamics: Pacemaker Syndrome



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

Stierle, PACE 1995;18:2028-34

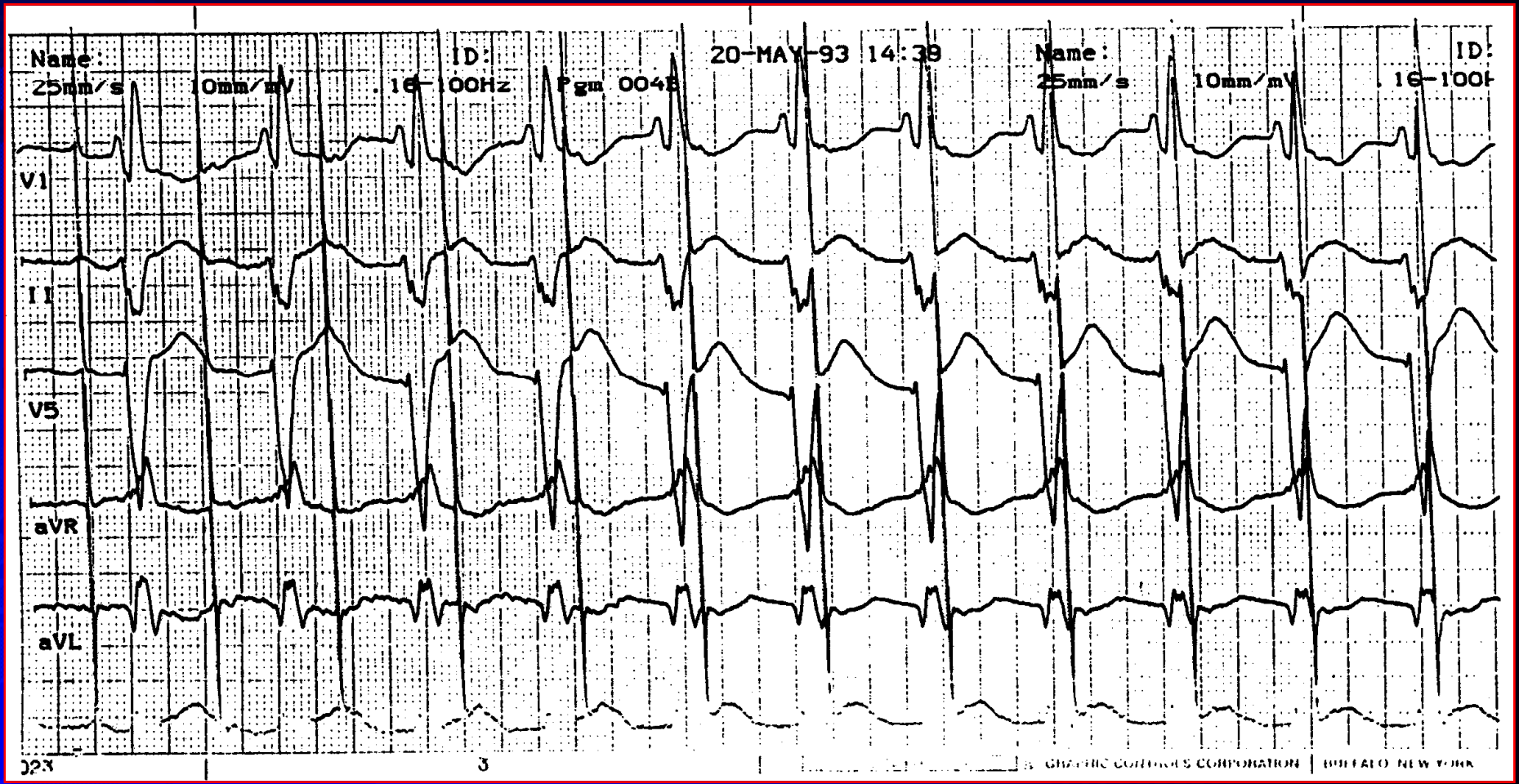
Hemodynamics: Pacemaker Syndrome



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

Stierle, PACE 1995;18:2028-34

Atypical Pacemaker Syndromes



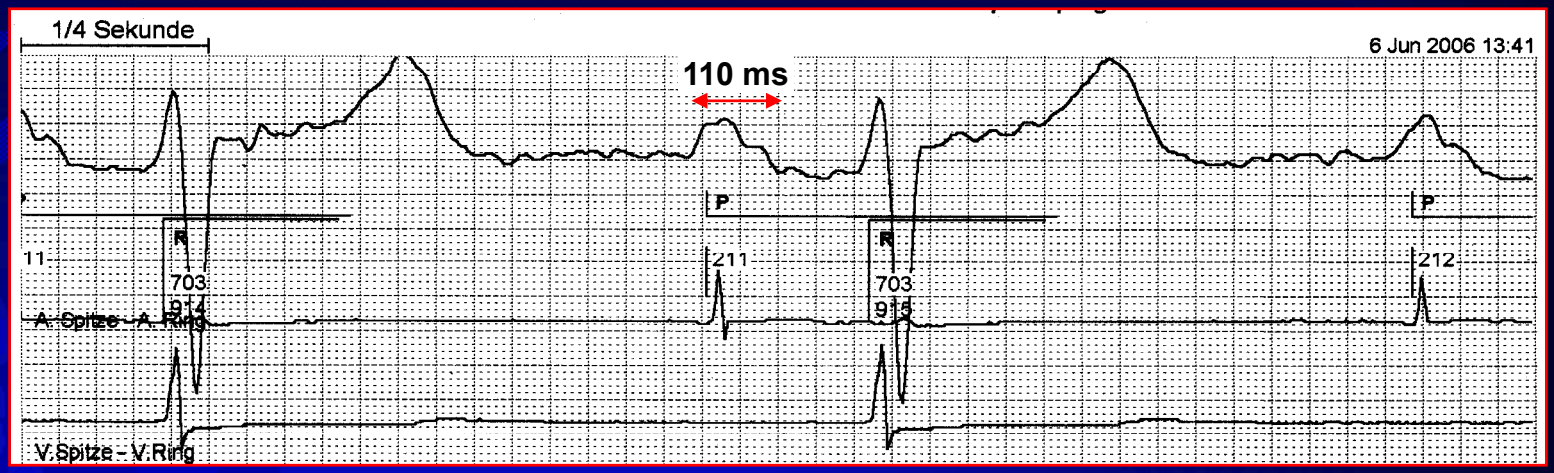
AAIR pacing with (extremely) long intrinsic AV conduction (stimulus-Q: 480 ms)

Hemodynamics of Pacing Mode

→ Pacemaker syndrome

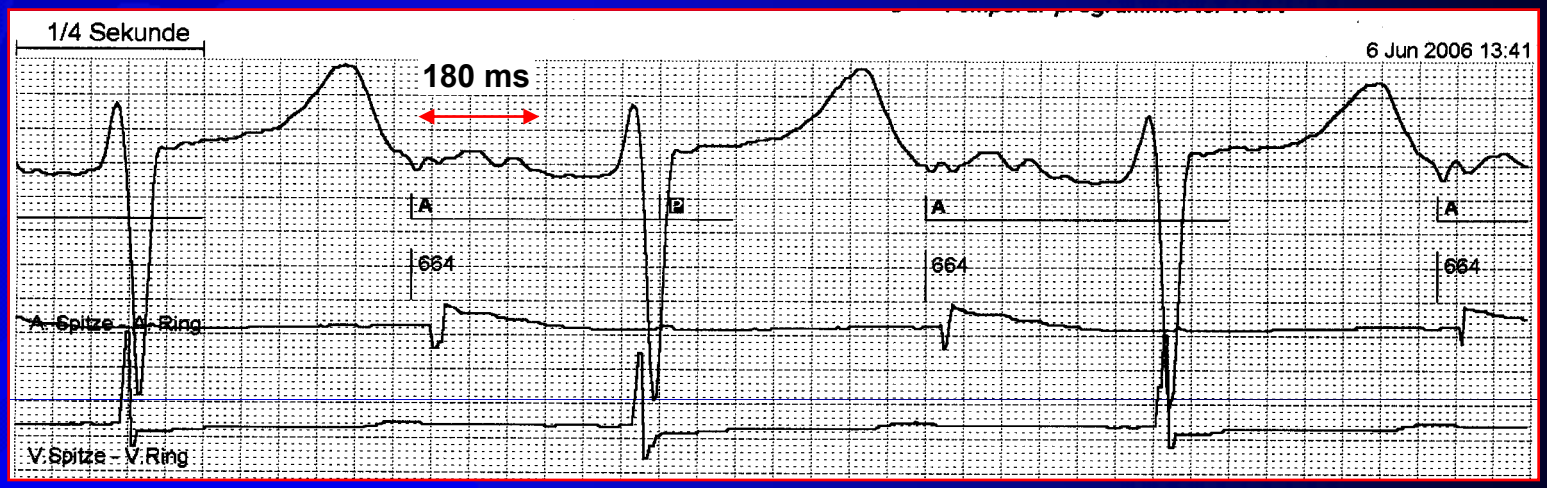
→ Atrial pacing

Atrial Pacing



Intrinsic P wave

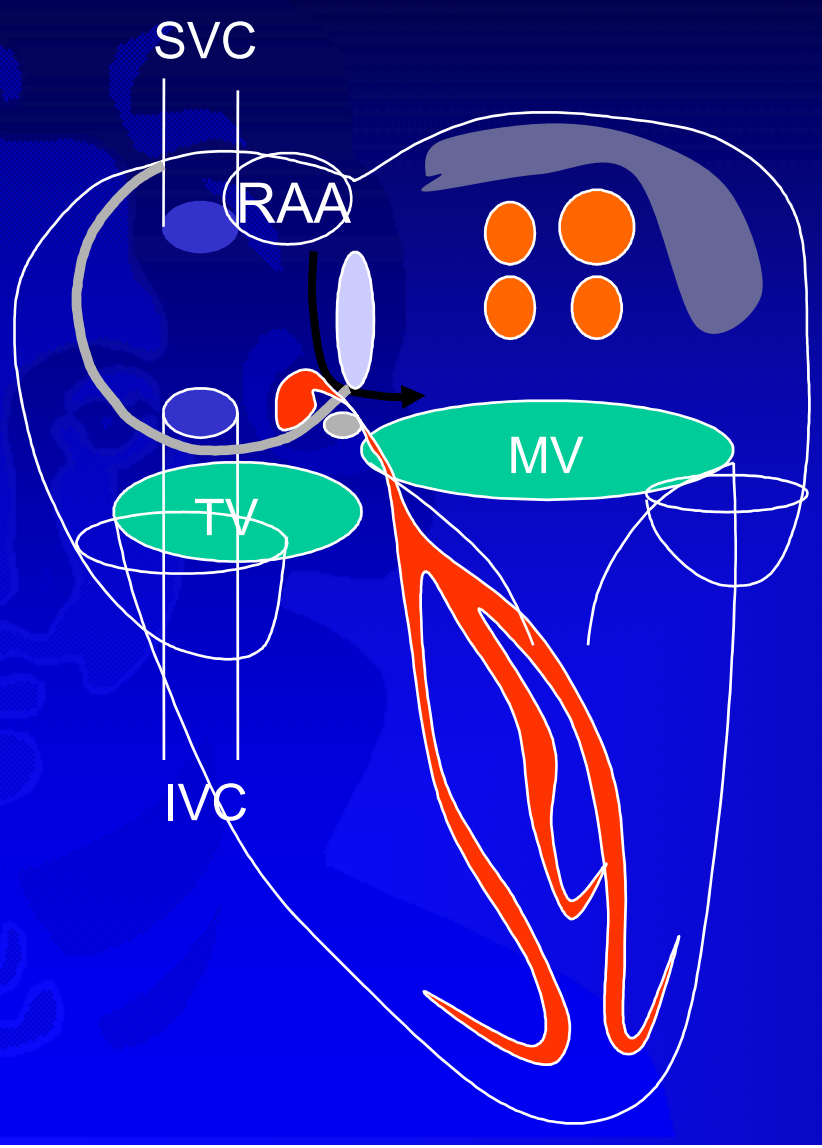
100 mm/s

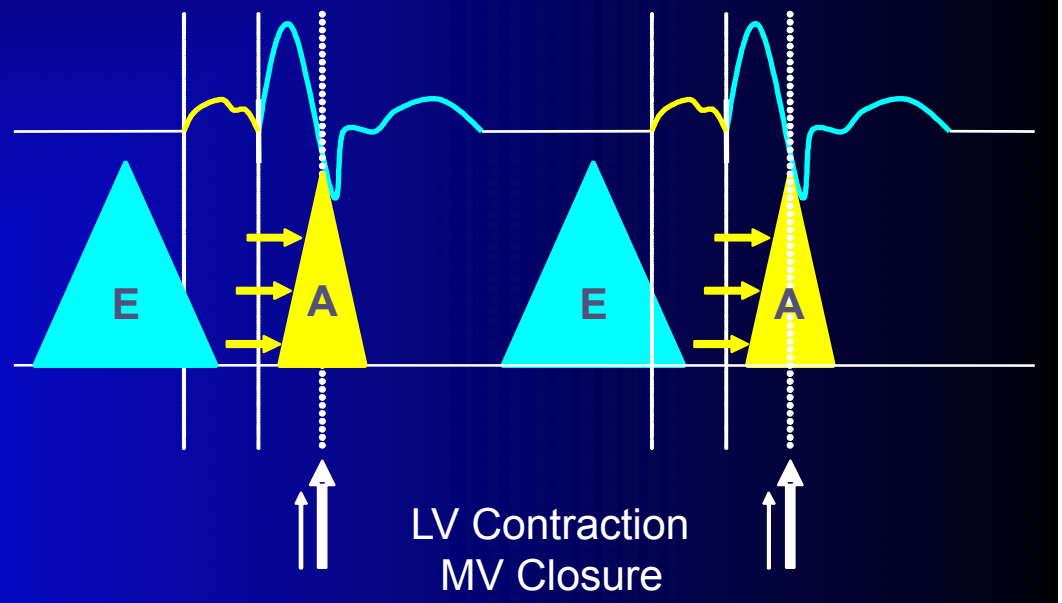


Paced P wave

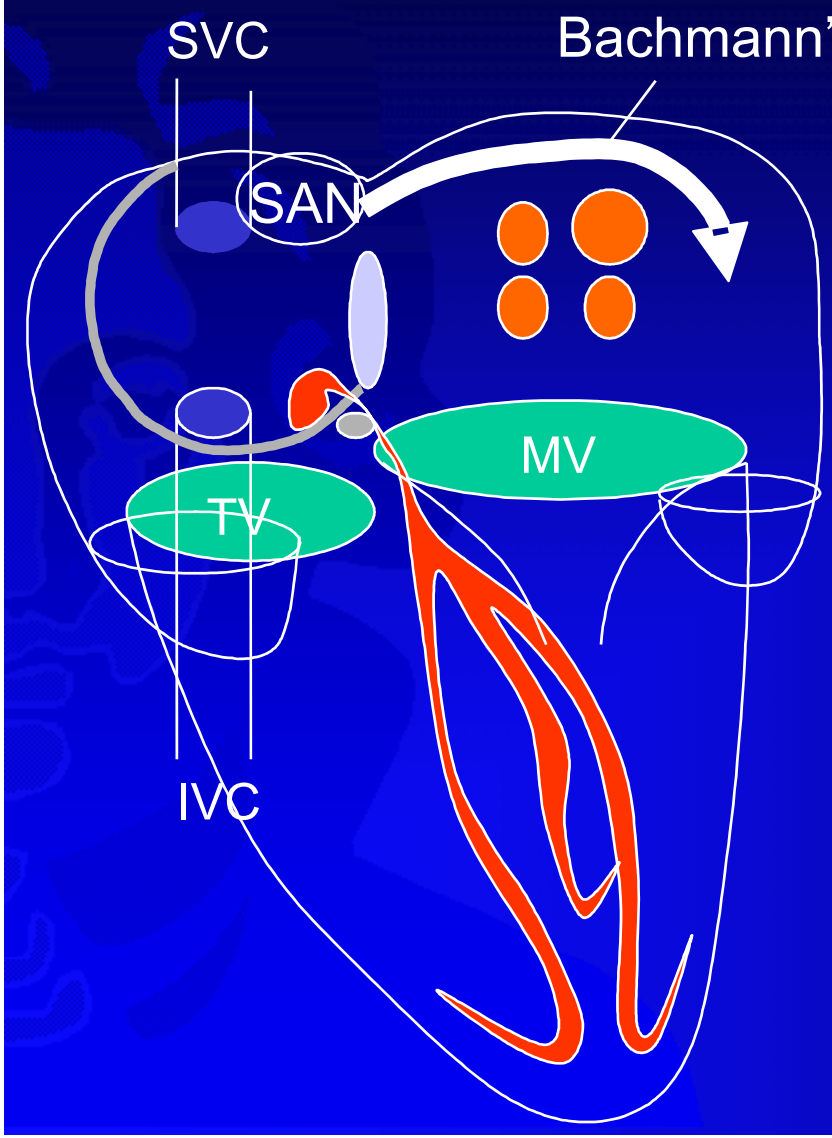
100 mm/s

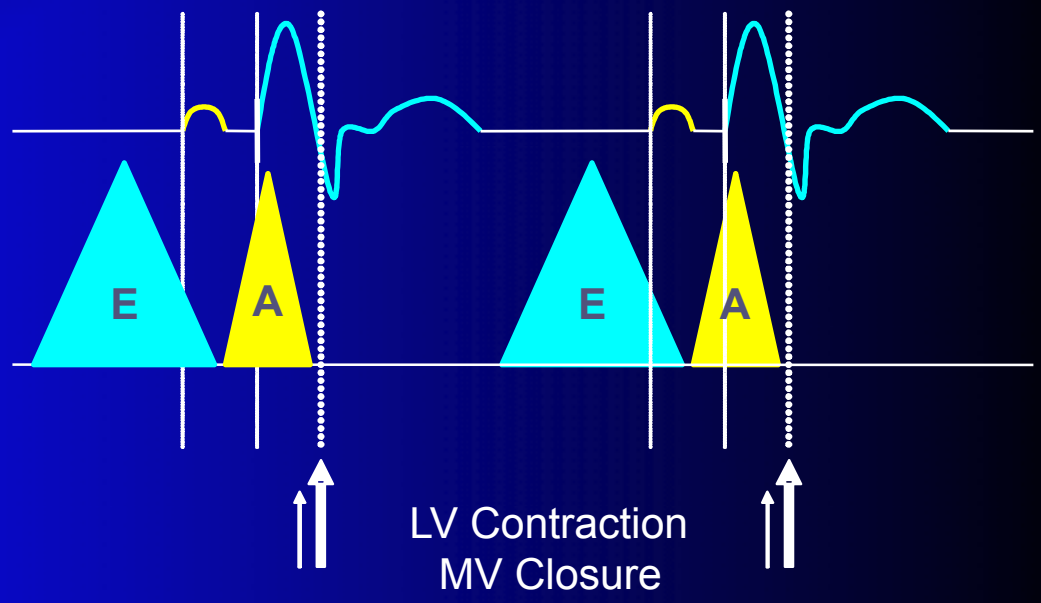
Atrial Pacing: RAA





Atrial Pacing: Septal





Hemodynamics of Pacing Mode

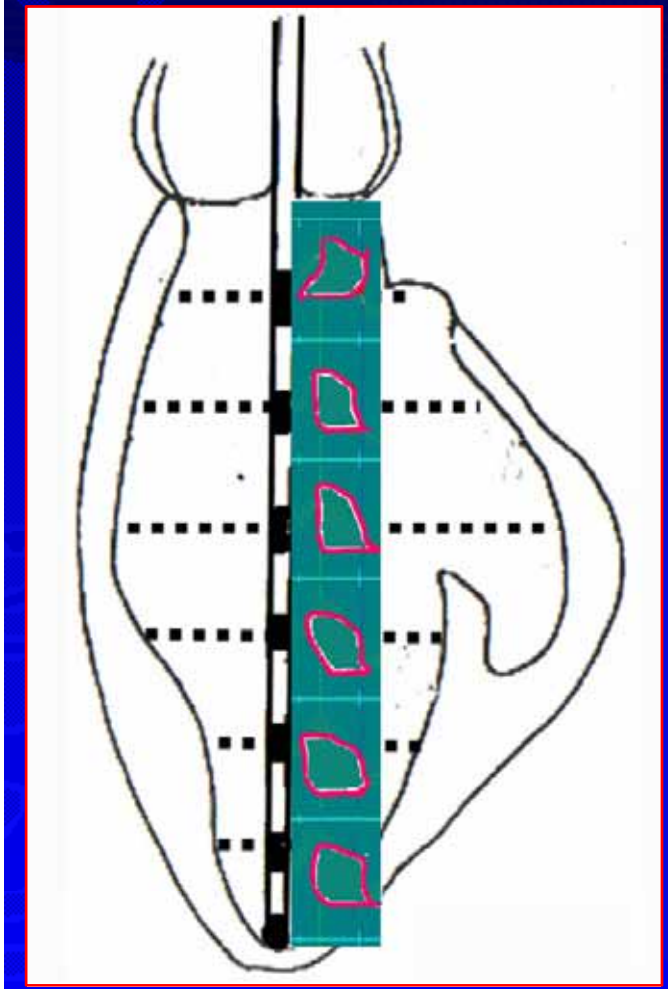
→ Pacemaker syndrome

→ Atrial pacing

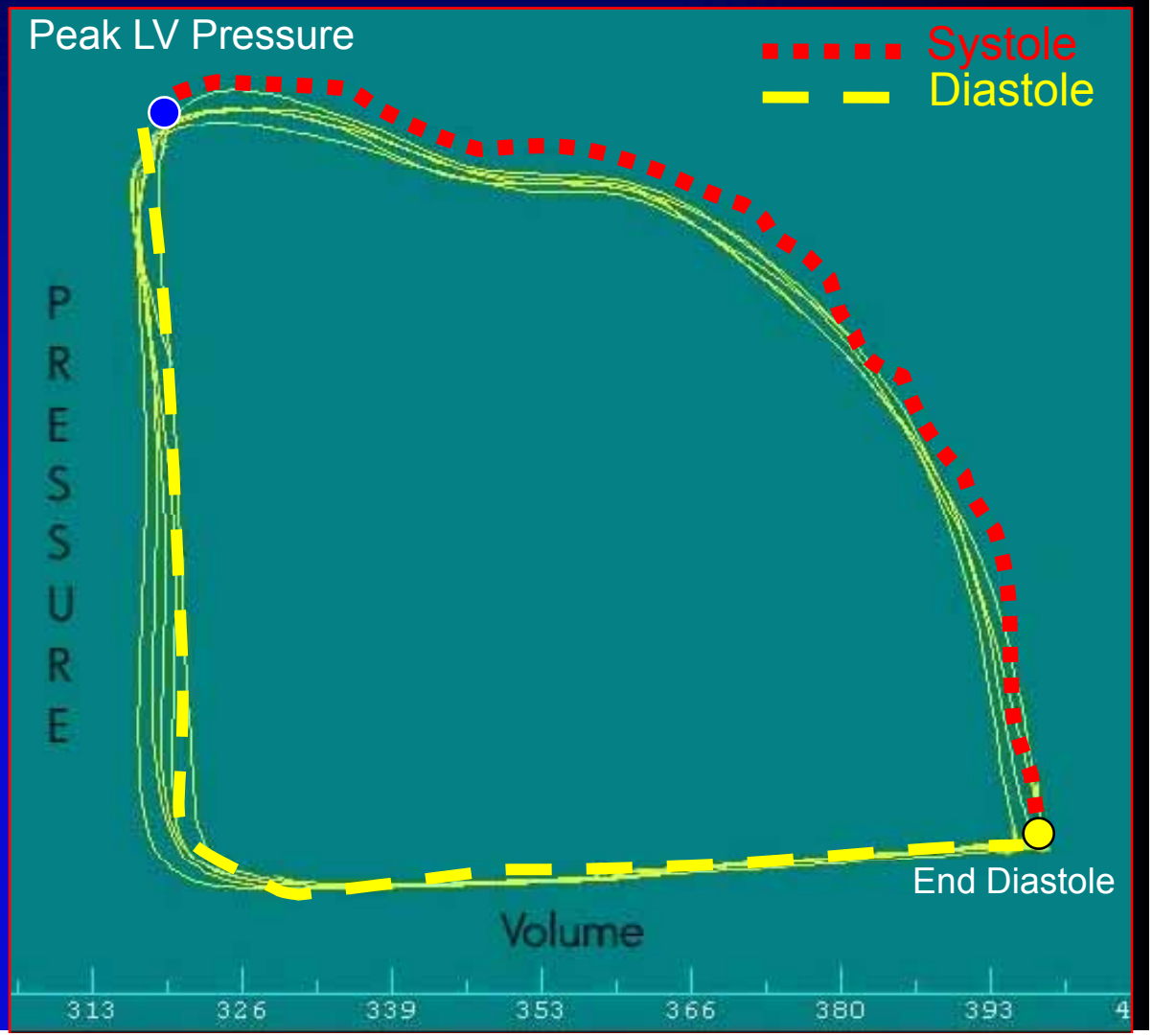
→ Right ventricular pacing

PV Loops for Evaluation of Intra-LV Synchrony

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



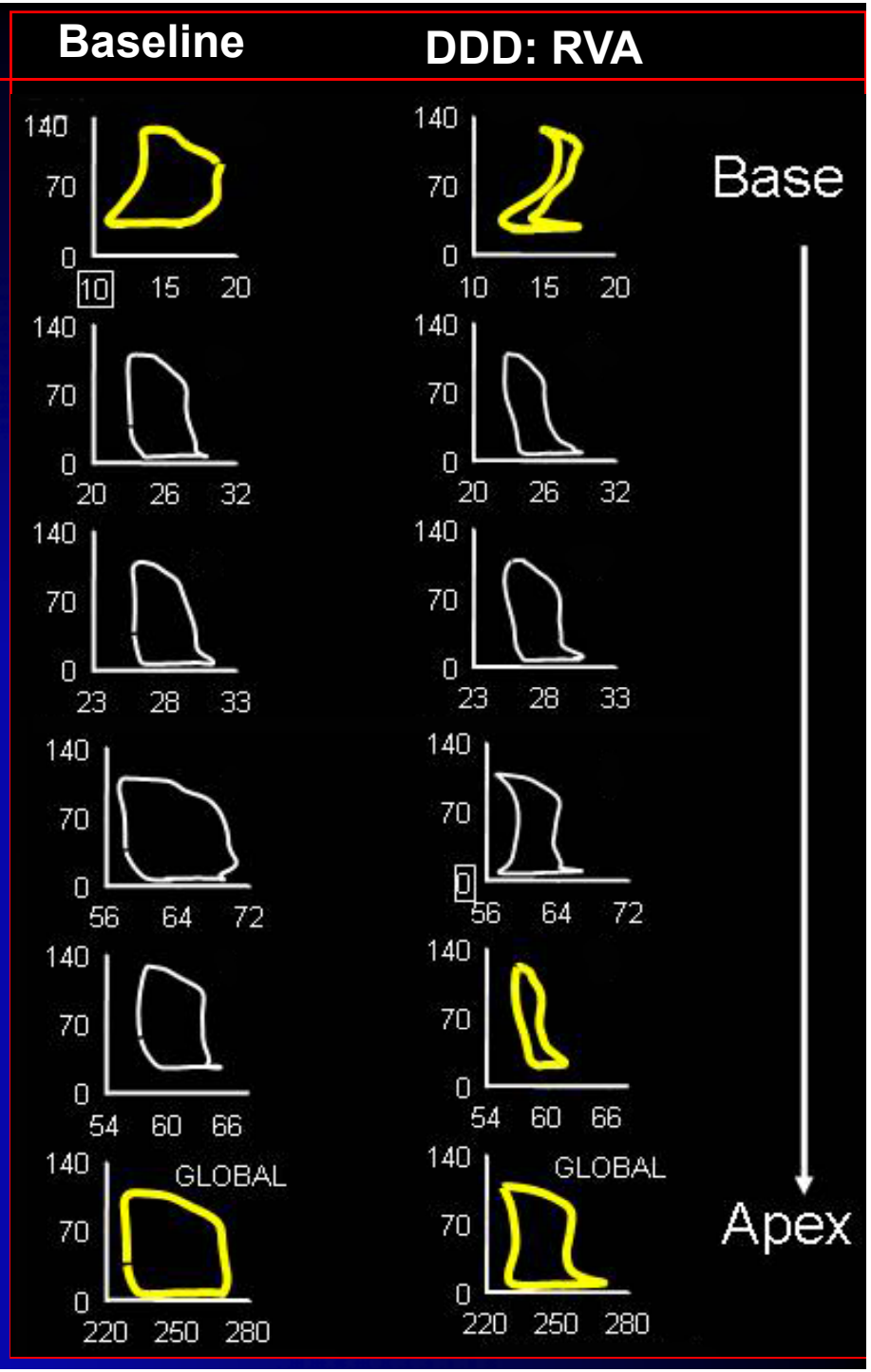
Lieberman, Circulation 2004;11:III-606



RVA Pacing-Mediated LV Dyssynchrony

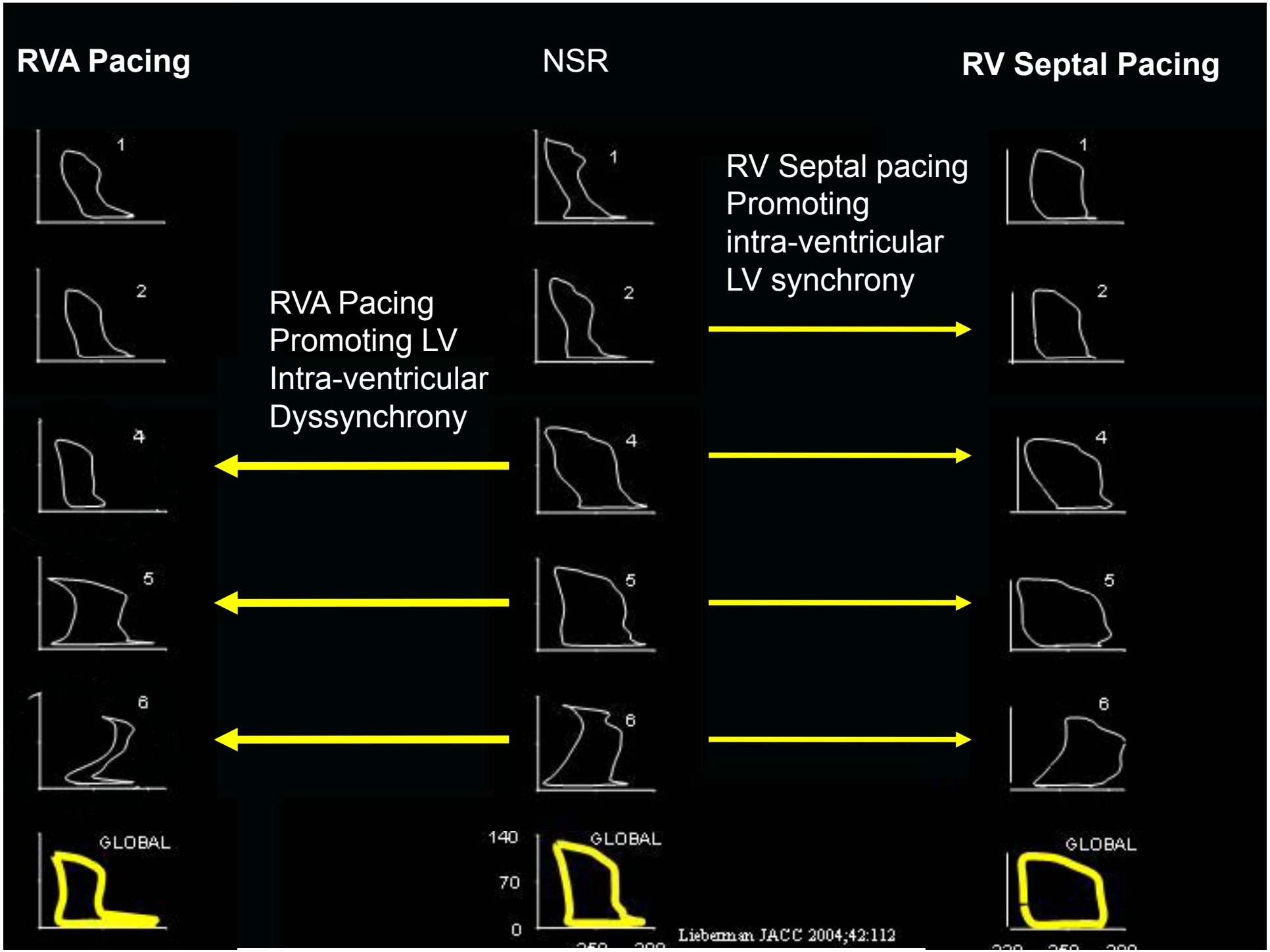
Baseline: all LV segments have relative square loops = intra LV Synchrony

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



Lieberman, Hettrick, Eastman Circulation 2004;11:III-606

Lieberman et al: JACC Vol 48: 2006


RVA Pacing
NSR
RV Septal Pacing
RV Septal pacing
Promoting
intra-ventricular
LV synchrony
RVA Pacing
Promoting LV
Intra-ventricular
Dyssynchrony
1
2
4
5
6
GLOBAL
140
70
0
Lieberman JACC 2004;42:112

Hemodynamics of Pacing Mode

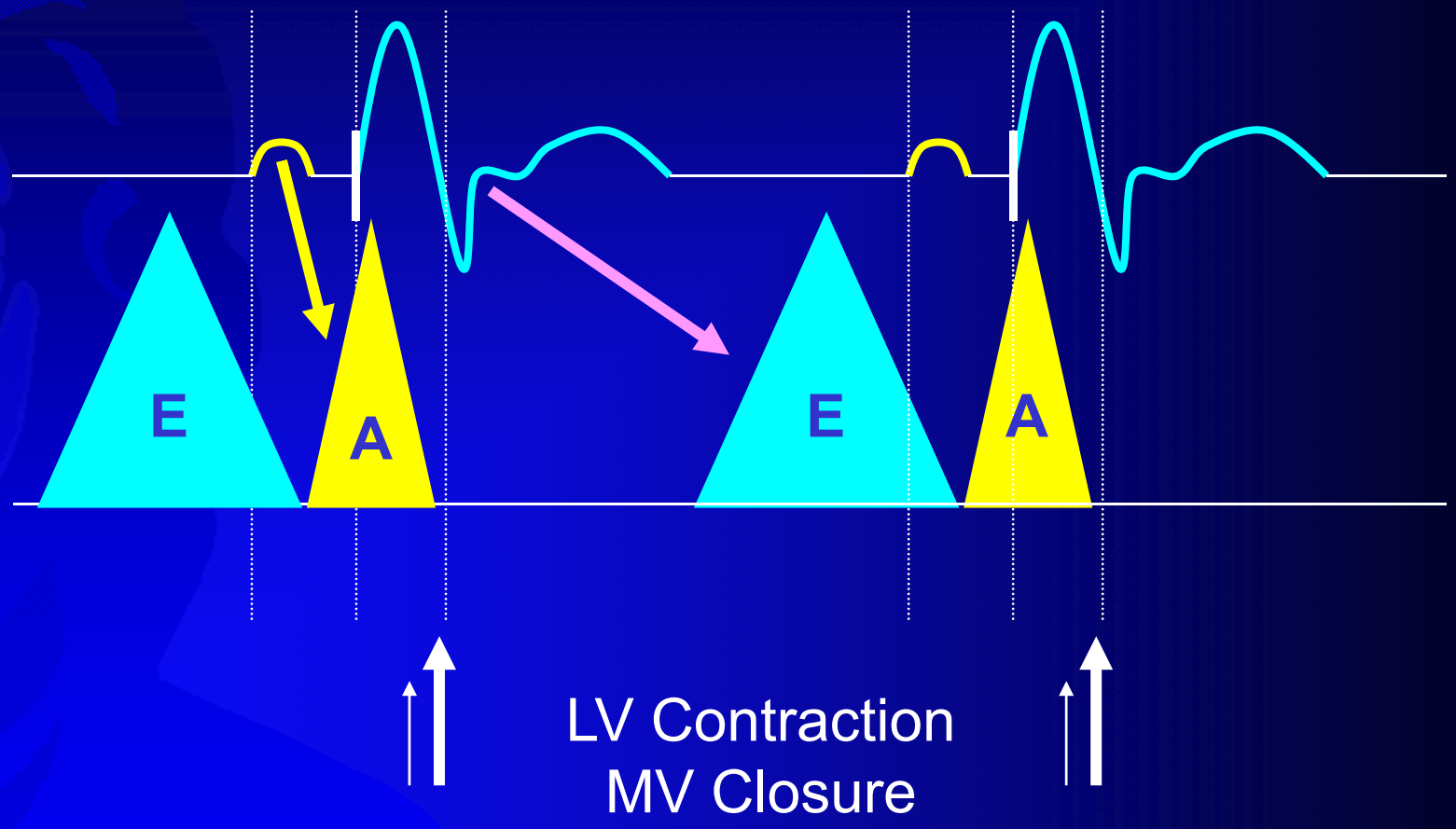
→ Pacemaker syndrome

→ Atrial pacing

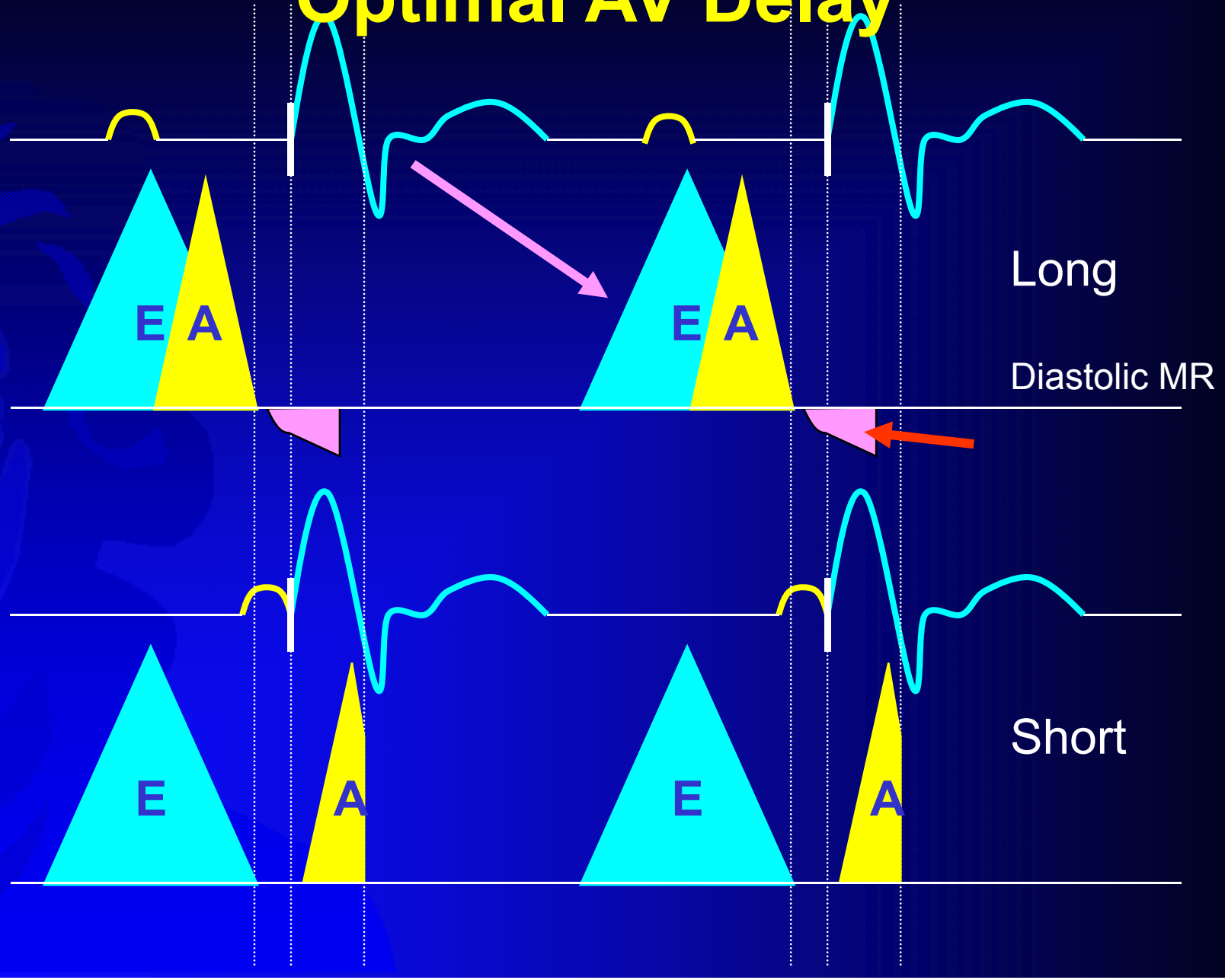
→ Right ventricular pacing

→ AV delay optimization

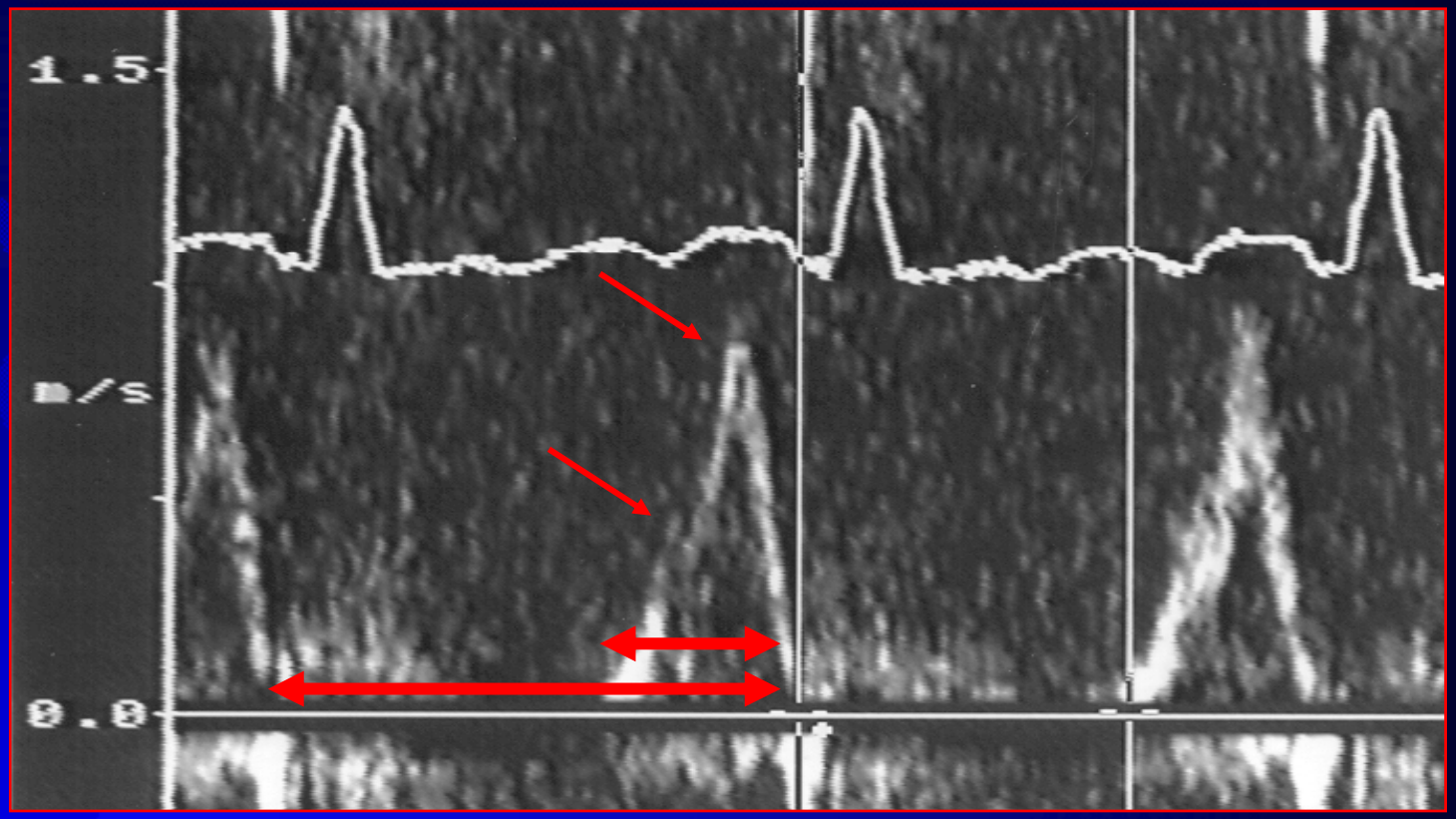
Optimal AV Delay



Optimal AV Delay



Diastolic Filling Time

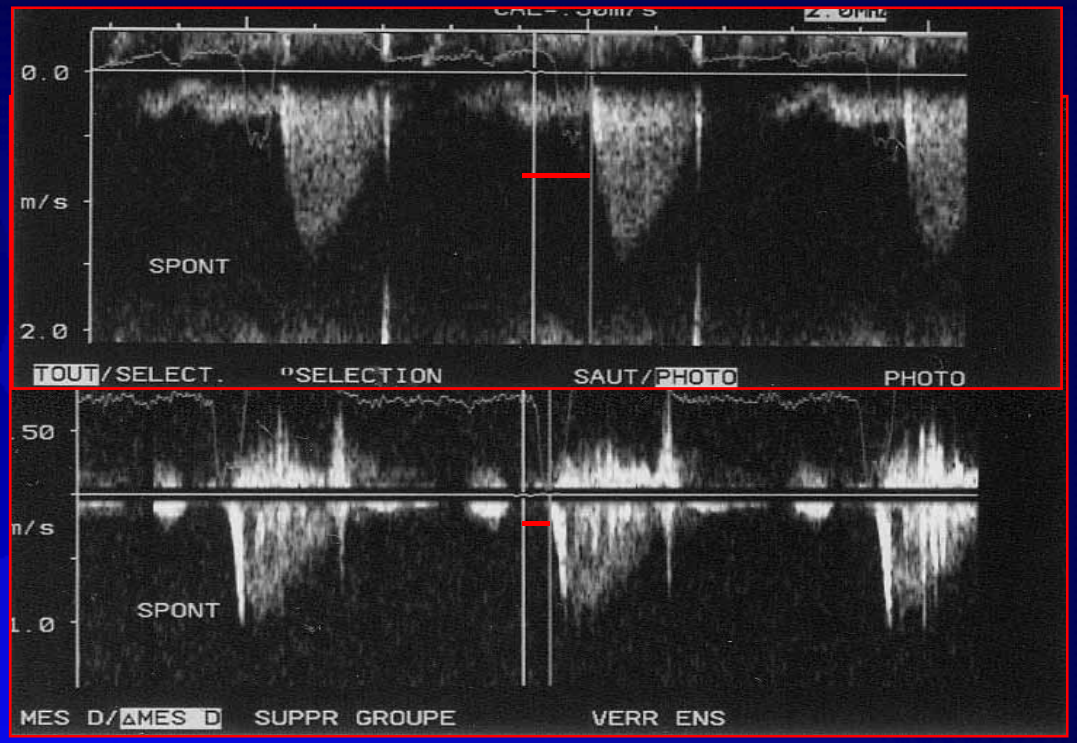


AV Dyssynchrony:

LVFT < 40% of the cardiac cycle

Cazeau Heart 2000; 84;579-581

Interventricular Dyssynchrony



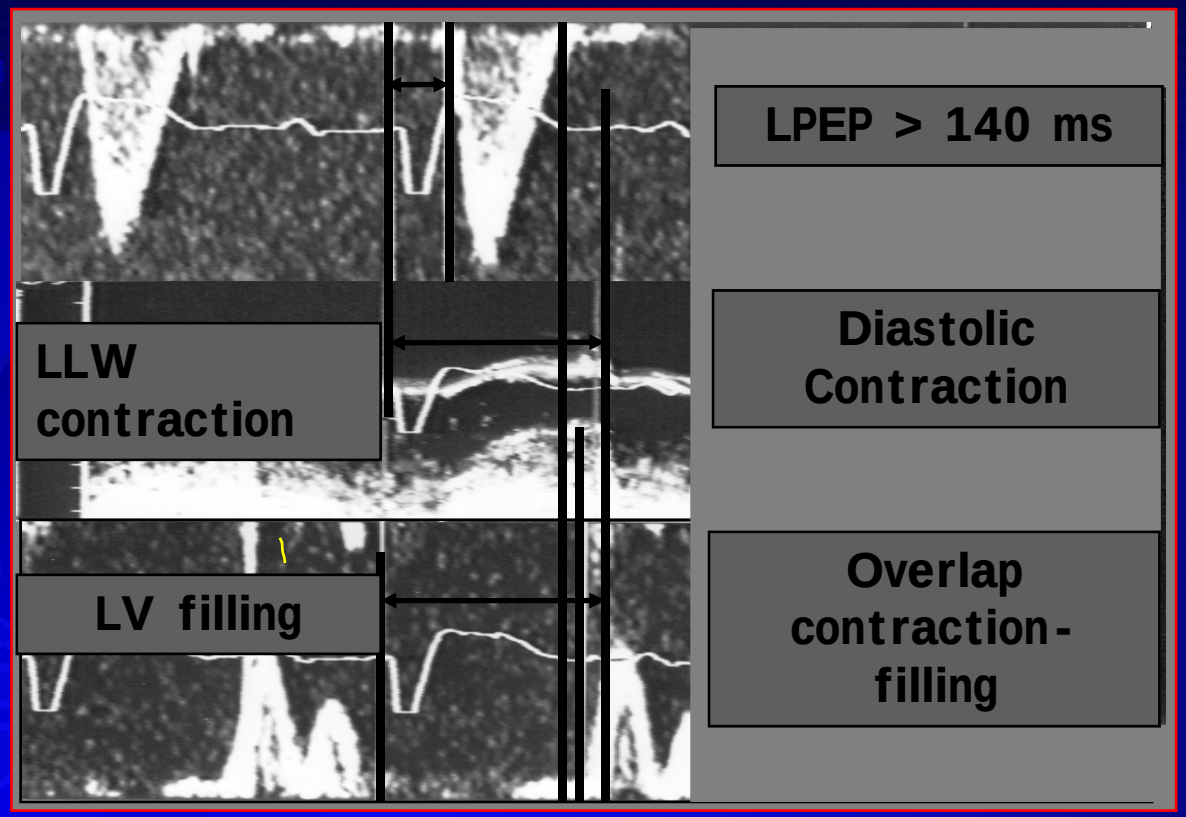
Interventricular Dyssynchrony

IVD = LPEP – RPEP > 40 ms

Aortic pre-ejection delay >140 ms

Cazeau Heart 2000; 84;579-581

Contraction/Filling Overlap



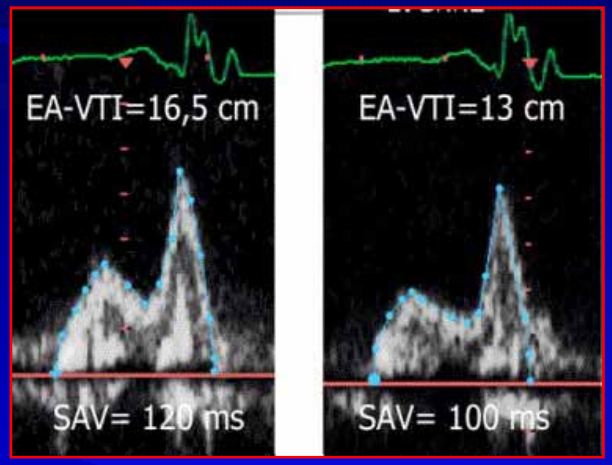
- part of ventricular contraction is not utilised toward ejection
- filling is impeded by persistent shortening along the long axis

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

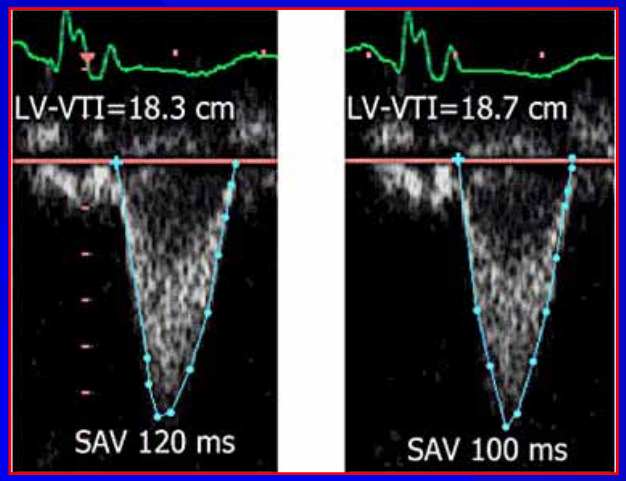
Cazeau Heart 2000; 84;579-581

Echo-Parameter for AV Delay Optimization in CRT

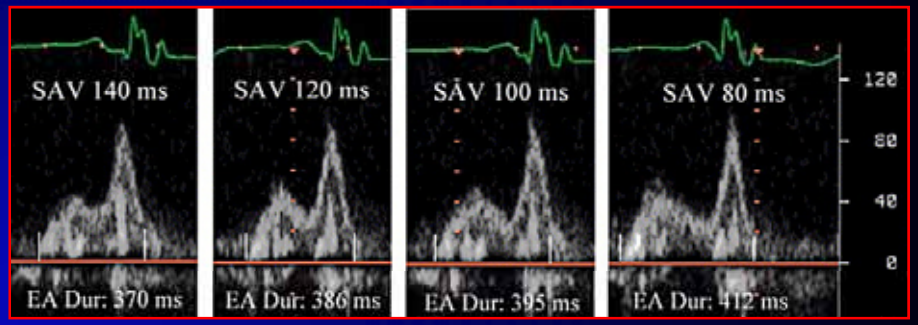
Mitral inflow E-A VTI



LVOT VTI

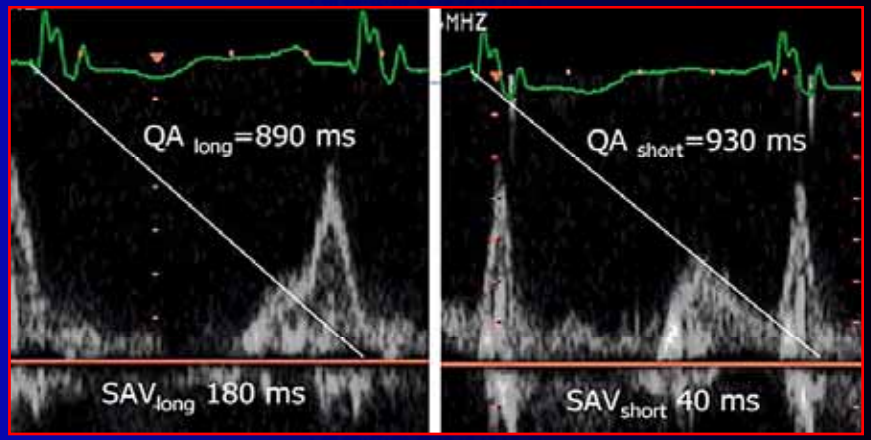


diastolic filling time (E-A duration)



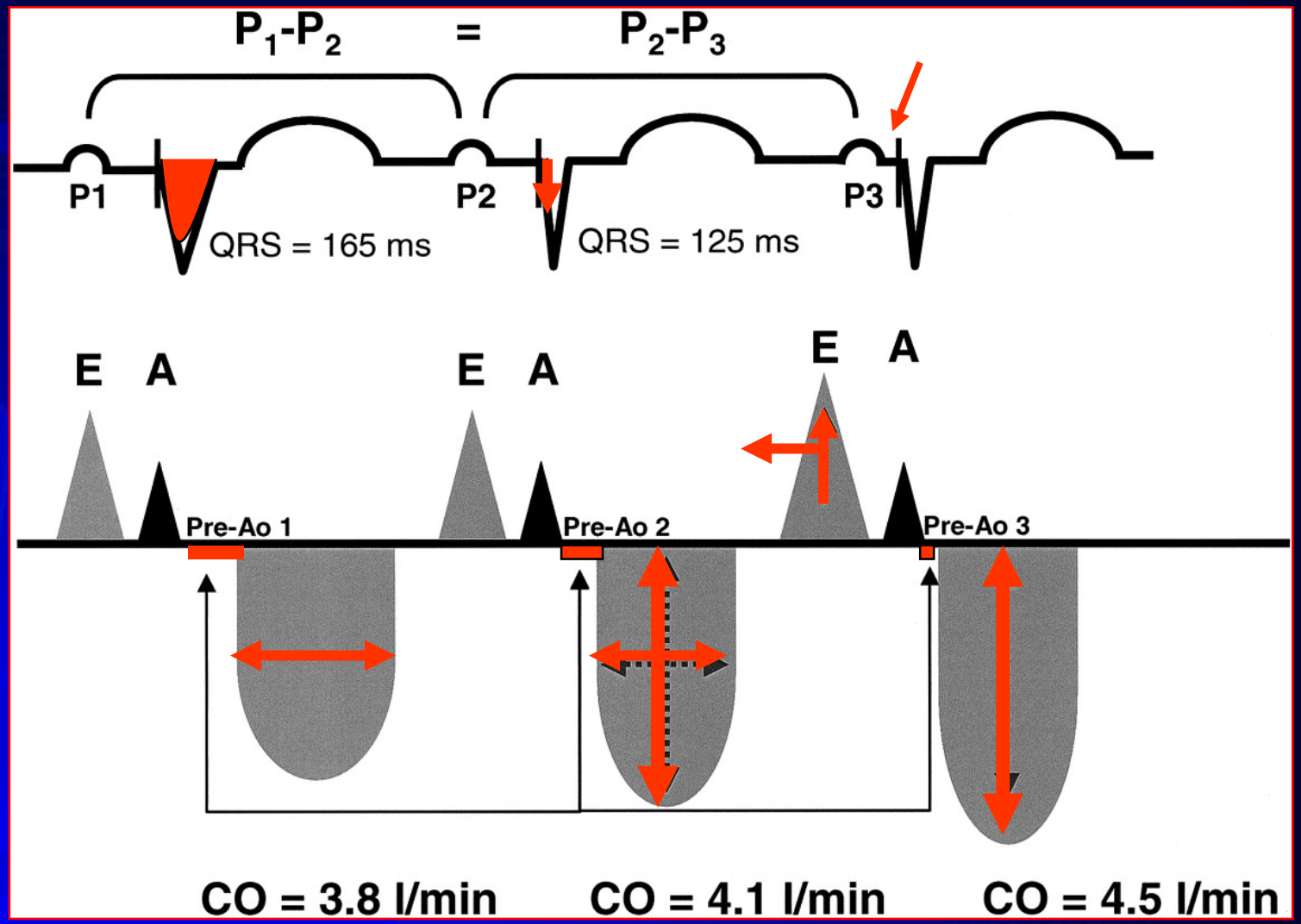
Ritter's formula

AV short + ([AV long + QA long] – [AV short + QA short])



Jansen, Am J Cardiol 2006;97:552-557

Isovolemic Contraction in CRT



Bax, J Am Coll Cardiol 2005;46:2168-82