The V Wave

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Ref: Kern MJ. Hemodynamic Rounds, 2nd ed. 1999.

Normal Hemodynamic Values

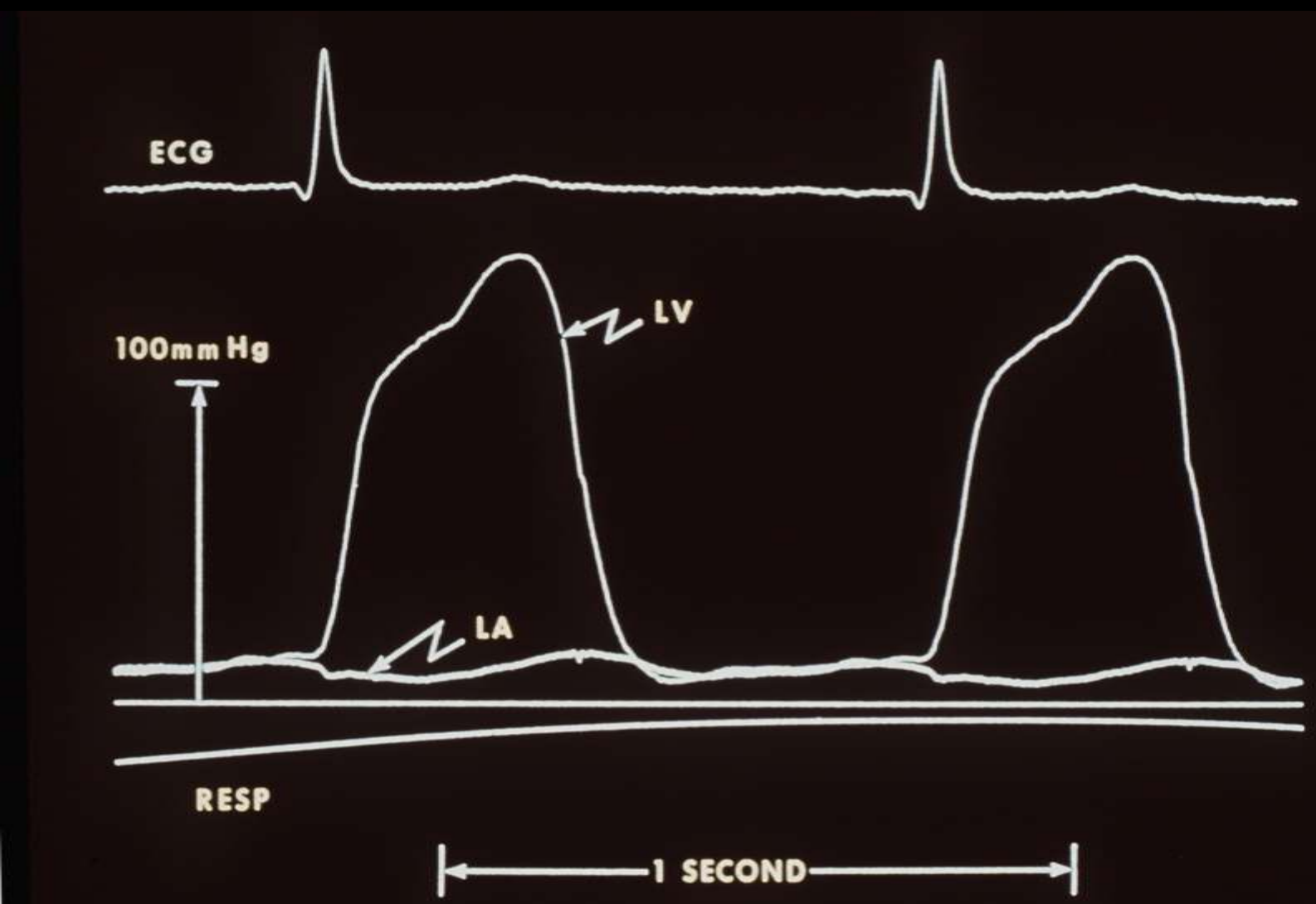
- Cardiac index 2.8-4.2 (mean 3.4 L/min/m^2)
- Stroke volume 30-65 (mean 47 mL/beat)
- A-V O2 Difference, mL/L blood 30-48 (mean 38)
- Brachial 90-140/60-90, mean 70-105 mmHg
- LVED 5-12
- LA or PAW 5-12
- PA 15-28/5-16, mean 10-22 (avg 16)
- RVED 0-8
- RA 0-8
- LV volume index (mL/m^2) EDV 50-90, ESV 15-25
- SVR 900-1400 (mean 1150 dyn*s/cm^5)
- PAR 45-120 (mean 70)

LeWinter MM et al. Chapter 4, Hurst, 11th ed. 2004, p.90

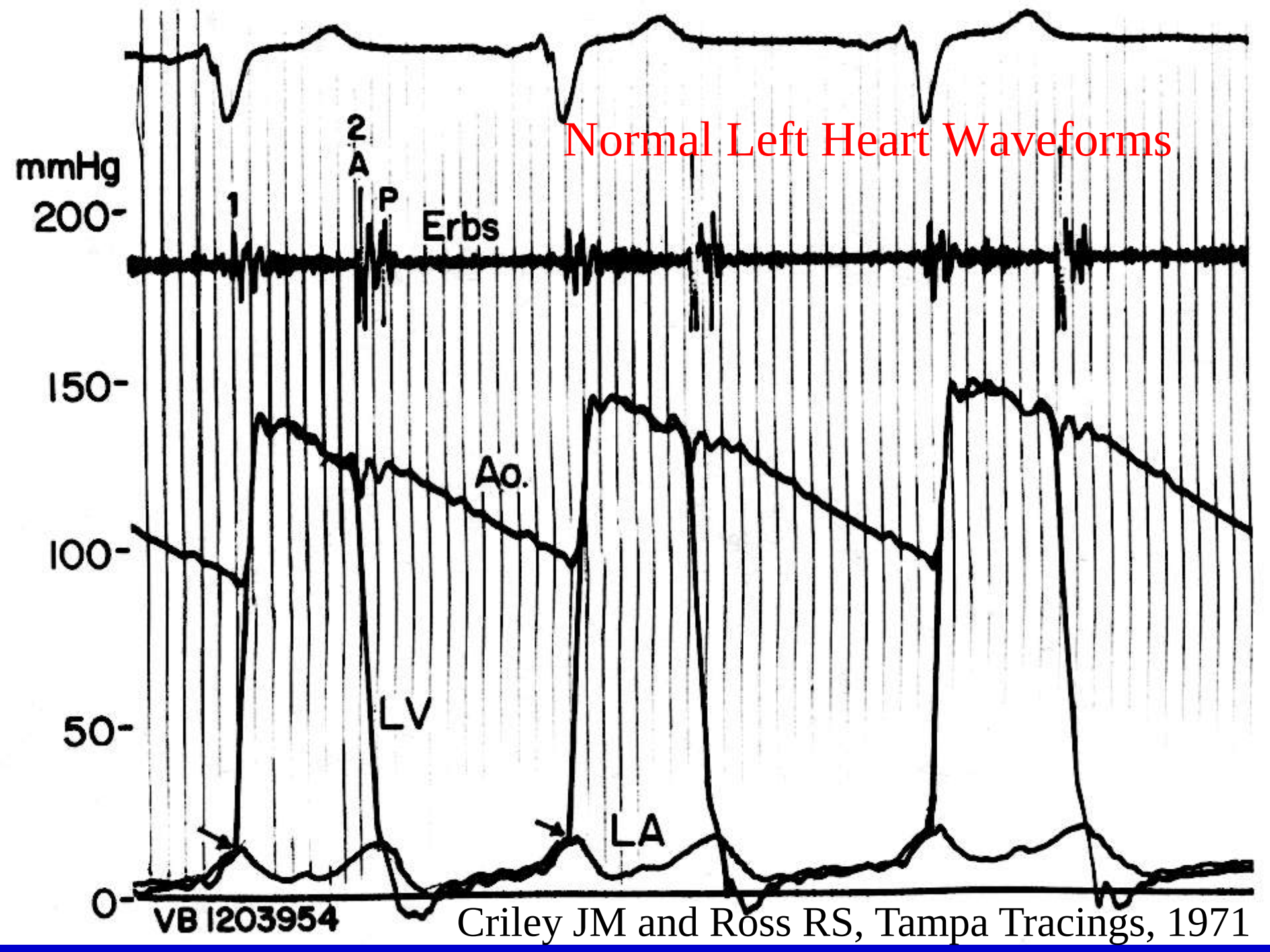
Normal Values Derived at BAMC

Location	Nml	Maximal	Resp Variation
• RA,a	9	?12	2
• RA.v	6	?12	2
• RA,X nadir	3-4		
• RA mean	6	8	2
• LA,a	10	16	
• LA,v	12		3-4
• LA mean	8	12	
• RV systolic	27	35	2-3
• RVED	5	7	1-2
• LV systolic	120	135	4-8
• LVED	10	12	3-4
• PA systolic	22	30	3-4
• PA diastolic	12	15	3-4
• PA mean	15-17	18 (20)	4-5

Normal Left Ventricular – Left Atrial Relationship



Normal Left Heart Waveforms



Criley JM and Ross RS, Tampa Tracings, 1971

Technique of V Wave Measurement

- PCW pressure versus direct LA pressure (Fluid-filled catheter systems)
  - 0.06 sec delay (Hurst, 10th ed. 2001, p.485, Kern co-author)
  - 50-70 msec delay (Grossman, 6th ed, p.198, 6th ed, p.109 Fig. legend)
  - 70 +/- 15 msec delay (mean±SD, Grossman 6th ed, p.109, Lange, JACC '89, wedge with 8F Goodale-Lubin, expect longer delay and more damping with smaller softer catheters)
  - 40-100 msec delay (Kern, p. 62)
  - 100-150 msec delay (Kern, Hurst, 11th ed. 2004, p. 519)
  - 140-200 msec delay (Kern, p. 94)
  - Alignment is by placing peak of V wave at or slightly to the left of (just before) the crossing of LV pressure (Grossman, 6th ed, p. 198)
  - Align the peak of the V wave to the downslope of the LV pressure (Kern, p. 62)
  - Y descent slope is less steep (Kern, p. 98)
  - LA pressure is overestimated by about 1.7 mmHg (Lange, 1989 as per Grossman, 6th ed p. 197; 2-4 mmHg per Kern, p. 62, 94)

PCW May Overestimate LA Pressure

- Acute respiratory failure
- Chronic obstructive lung disease with pulmonary hypertension
- Pulmonary venoconstriction
- LV failure with volume overload
- Technical factors
  - Different types of catheters

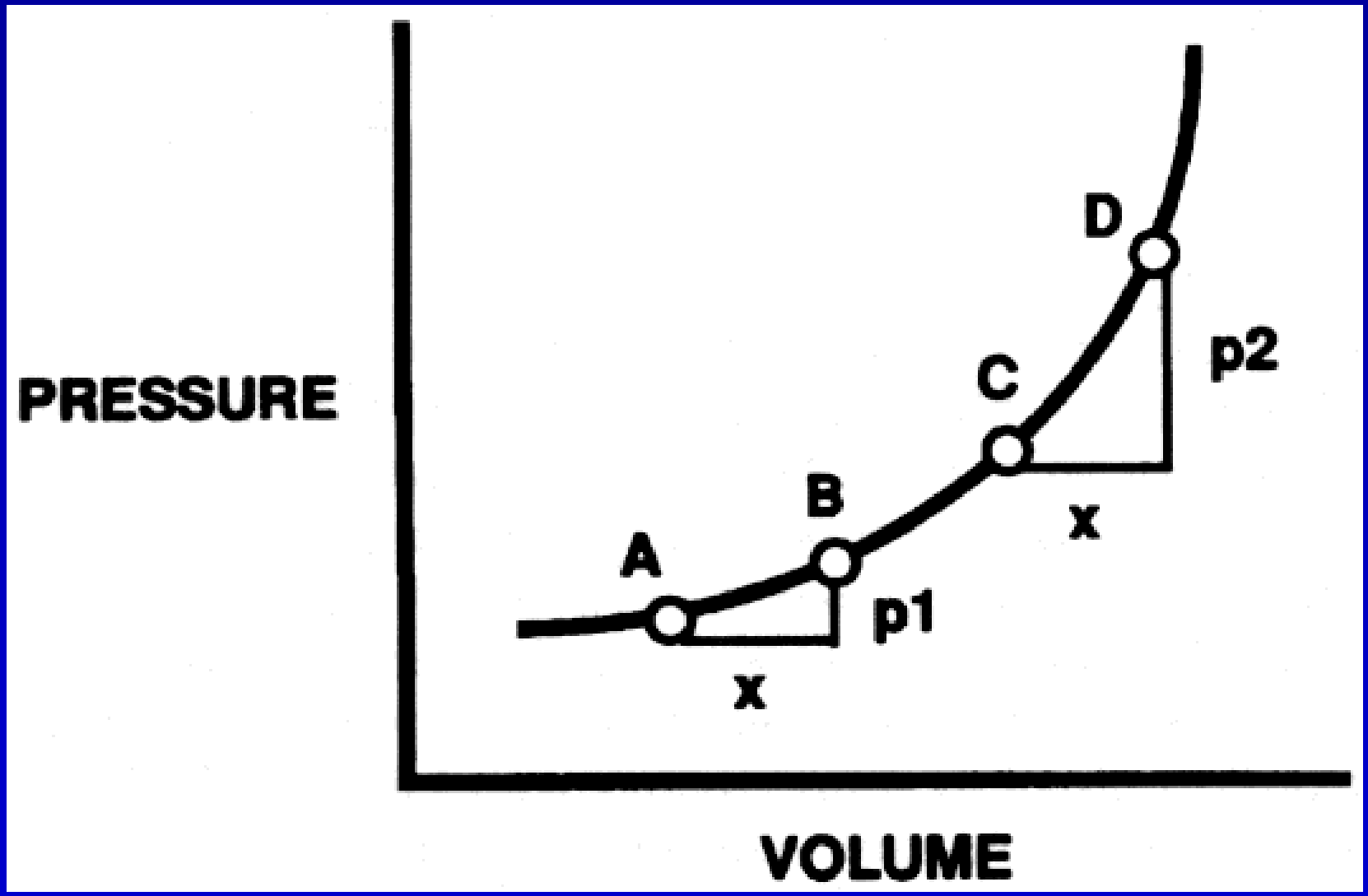
Kern MJ et al. Chapter 17. Hurst, 11th ed. 2004; p. 512

Assessing the LA V Wave

- V wave peak of twice mean pressure may be seen without significant MR, but is suggestive of severe MR
- V wave peak of three times mean pressure almost certainly indicates severe MR
- Normal V wave doesn't exclude severe MR at all
- LV failure from any cause can give large V wave (distended LA becomes relatively noncompliant)
- High pulmonary blood flow can give large V wave (acute VSD) even >50mmHg

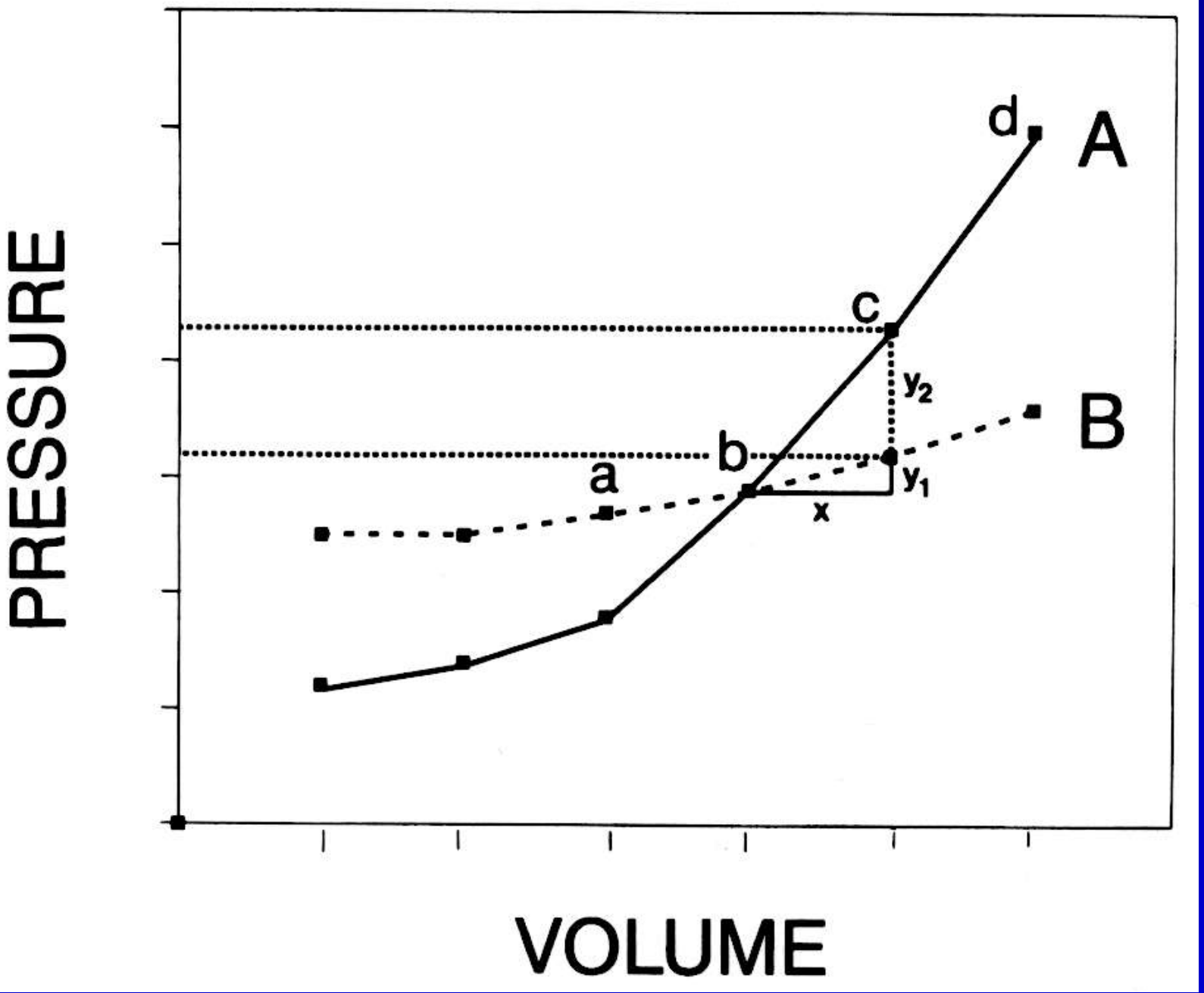
Grossman, 6th ed, 2000; p. 766

Hypothetical LA Diastolic P/V Curves



Tice FD et al. Am J Cardiol. 1995;75:58-60.

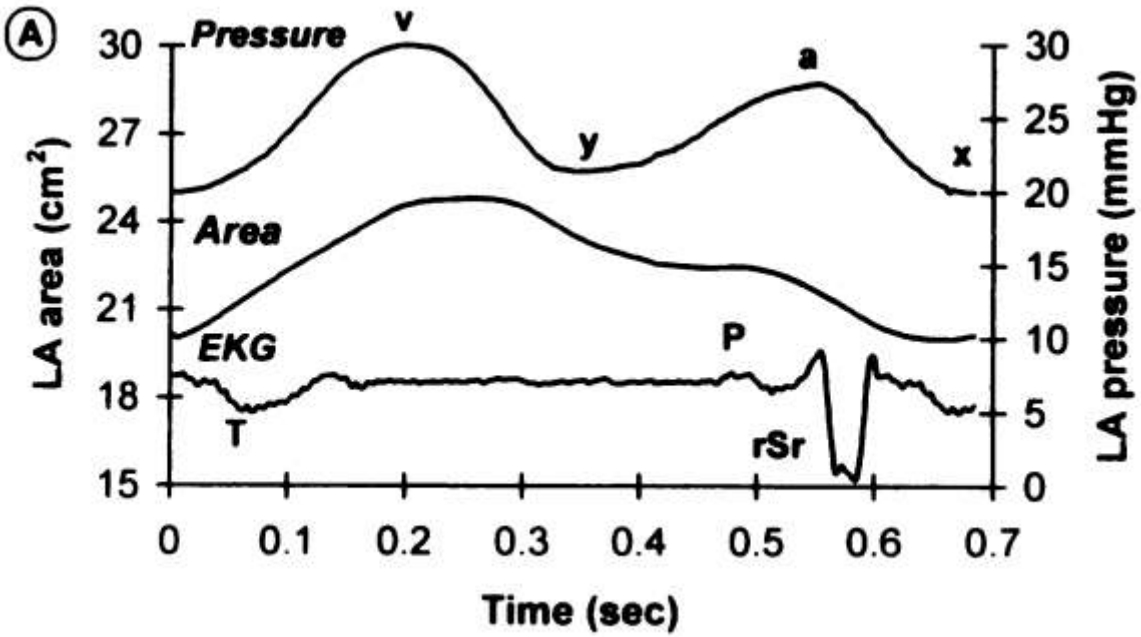
Hypothetical LA Diastolic P/V Curves

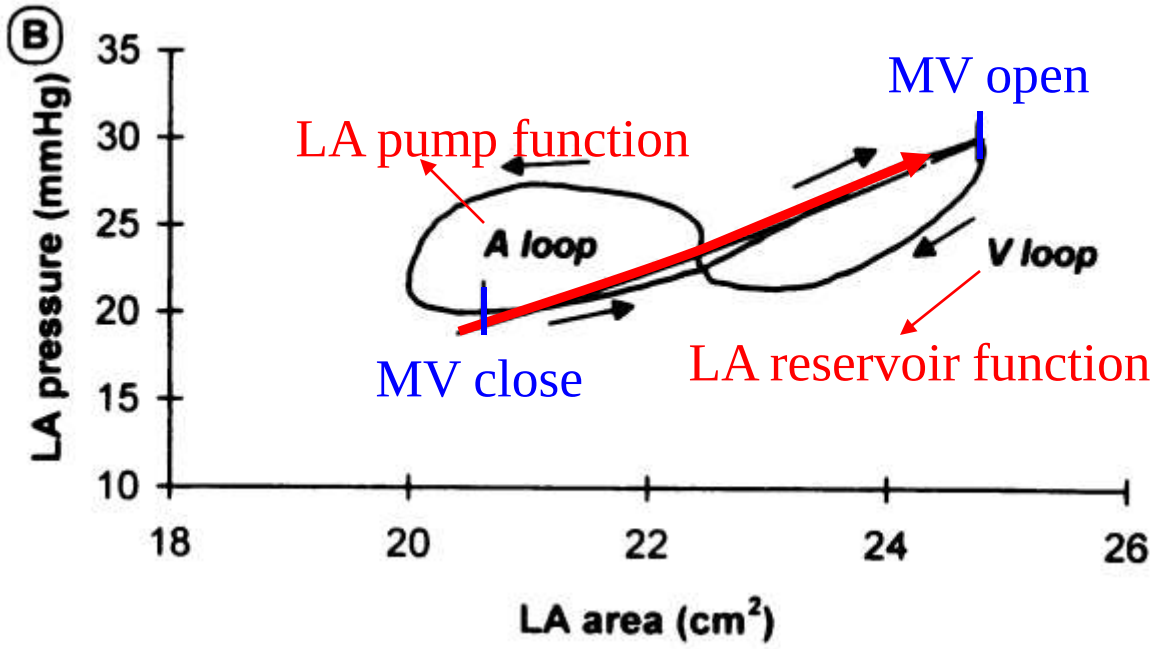


Kern, 1999, p. 96 A = noncompliant; B = compliant

V Wave Physiology

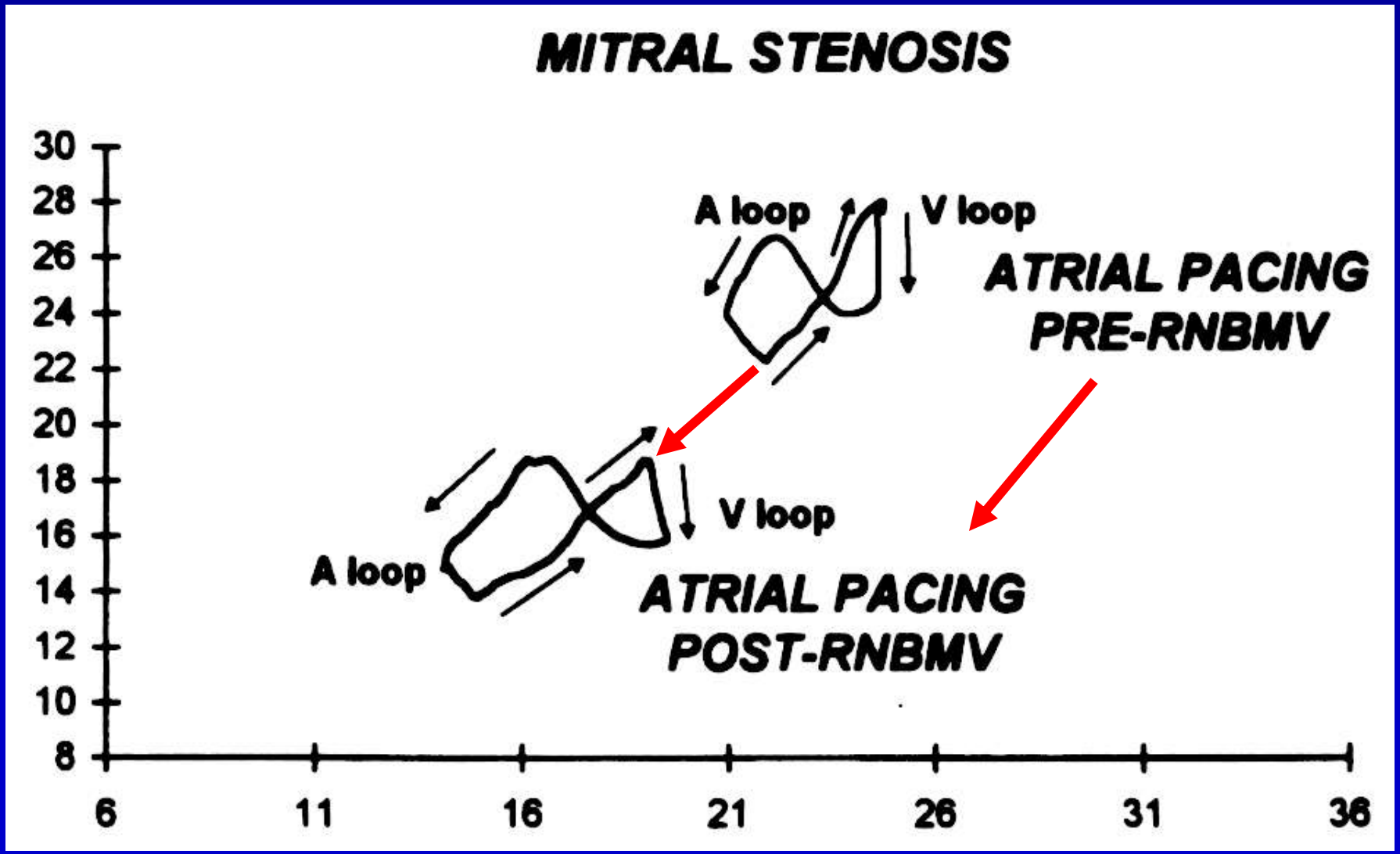
- Atrial three phases in the cardiac cycle:
  - Reservoir (ventricular systole)
  - Conduit (ventricular diastole)
  - Contraction (atrial systole)
- Pressure increases as volume increases
  - Depends on chamber compliance
  - Depends on rate… there are viscous forces
  - Curvilinear





Stefanadis C et al. JACC. 1998;32:159. Human, hi-fi pressure, echo LA area automated

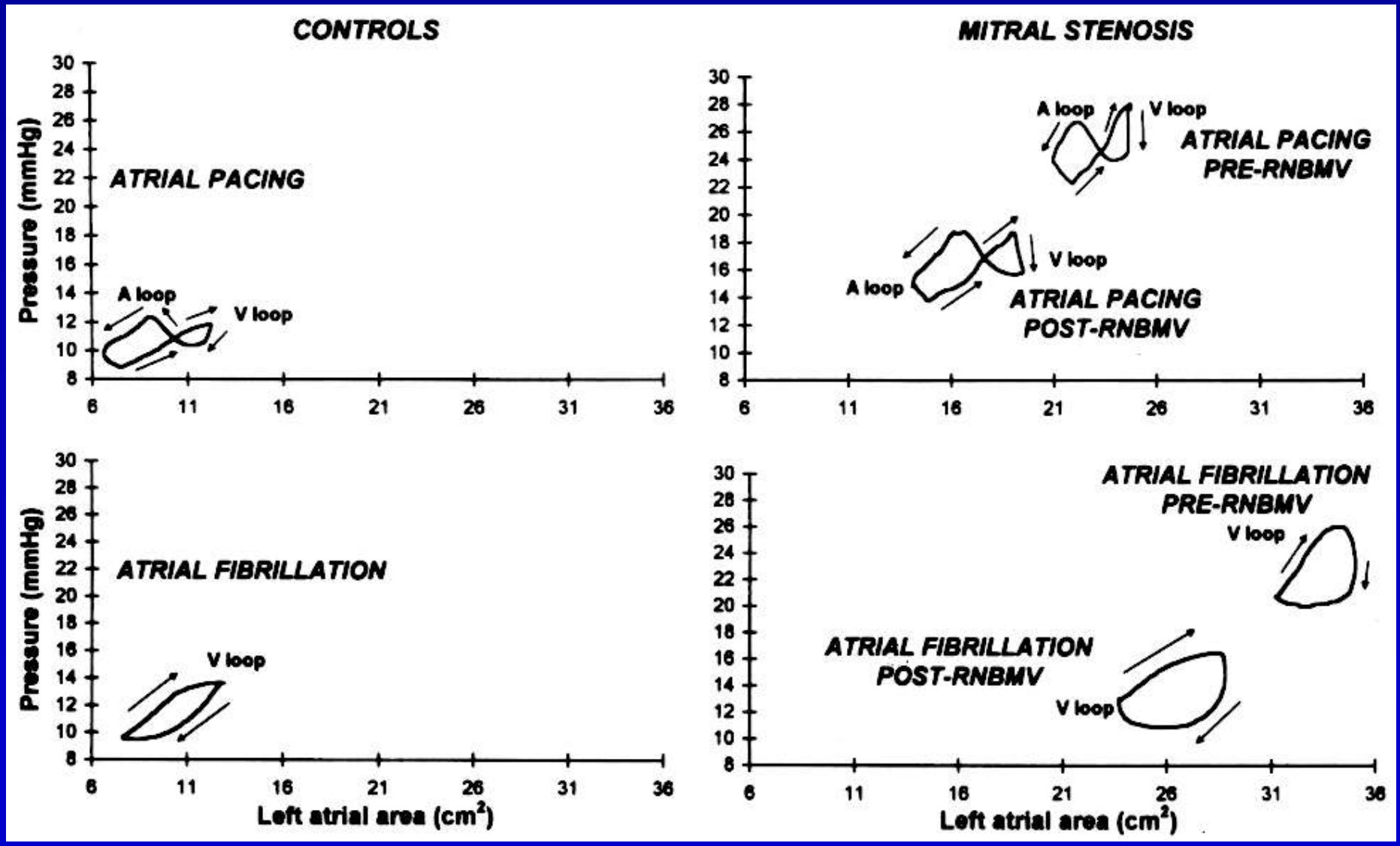
V Wave Physiology



Stefanadis C et al. JACC. 1998;32:159

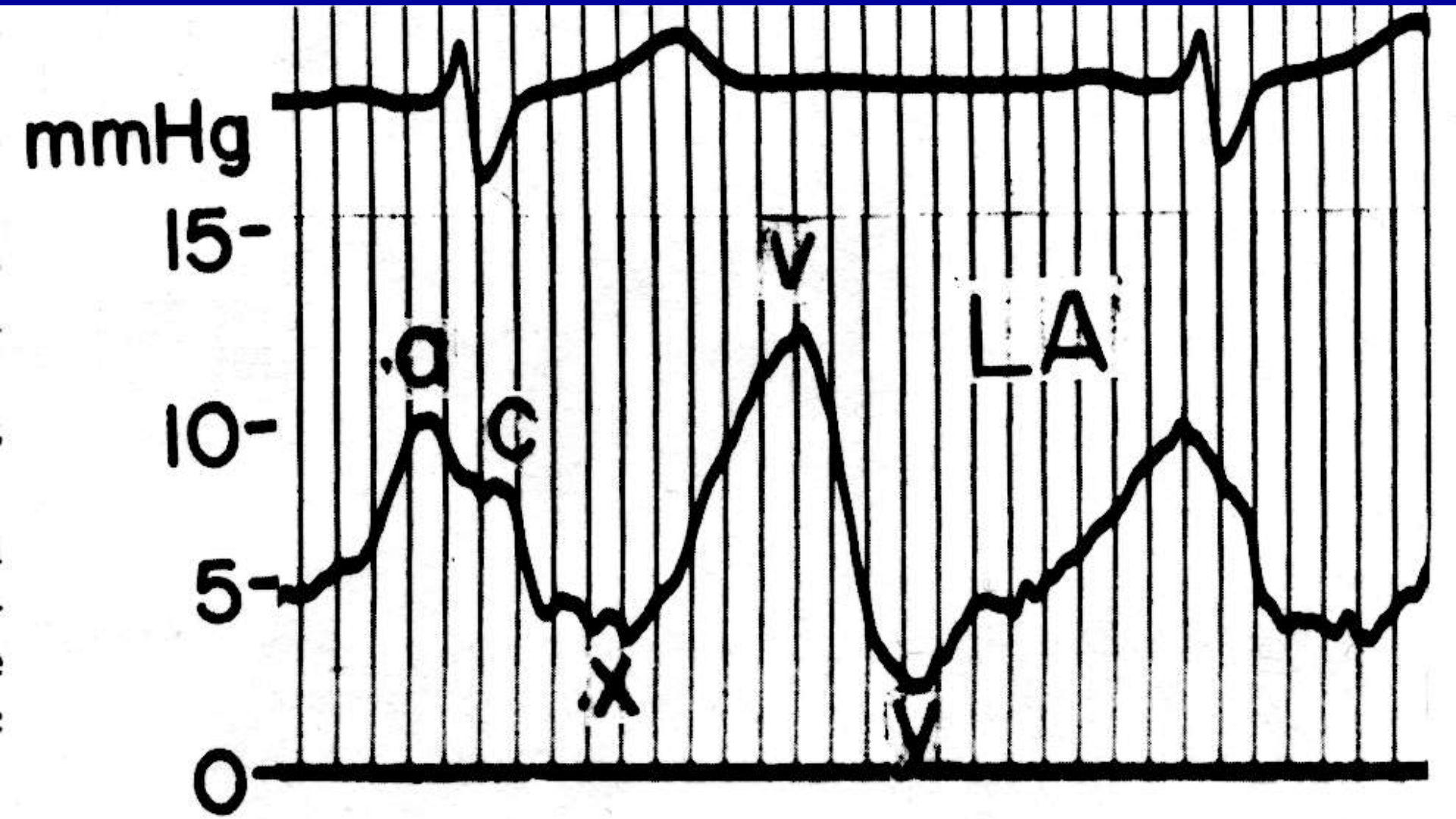
RNBMV – retrograde nontransseptal balloon mitral valvuloplasty

V Wave Physiology



Stefanadis C et al. JACC. 1998;32:159

Normal LA Pressure Waveform



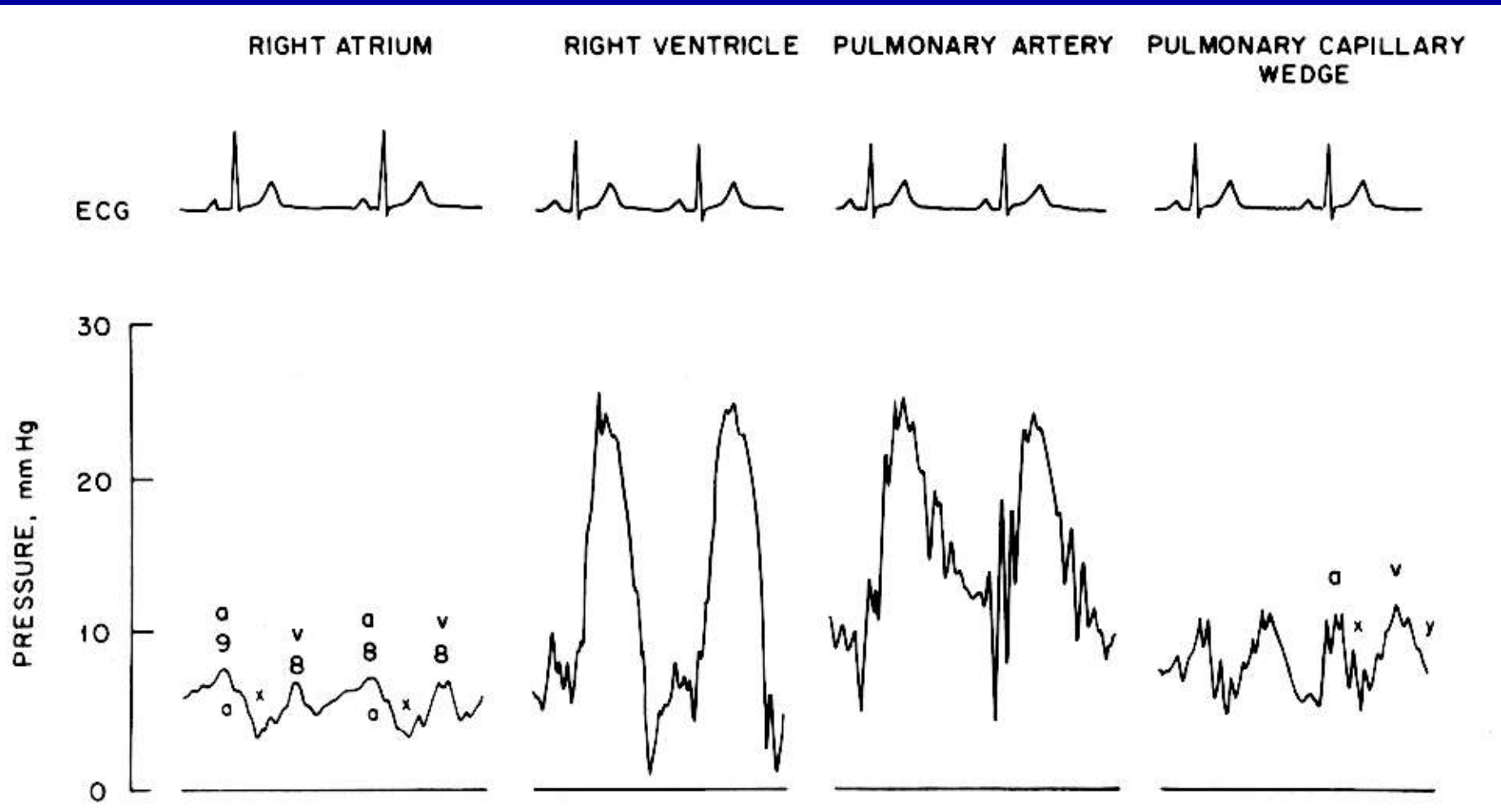
Criley JM and Ross RS, Tampa Tracings, 1971

Summary: Causes of Large V Wave

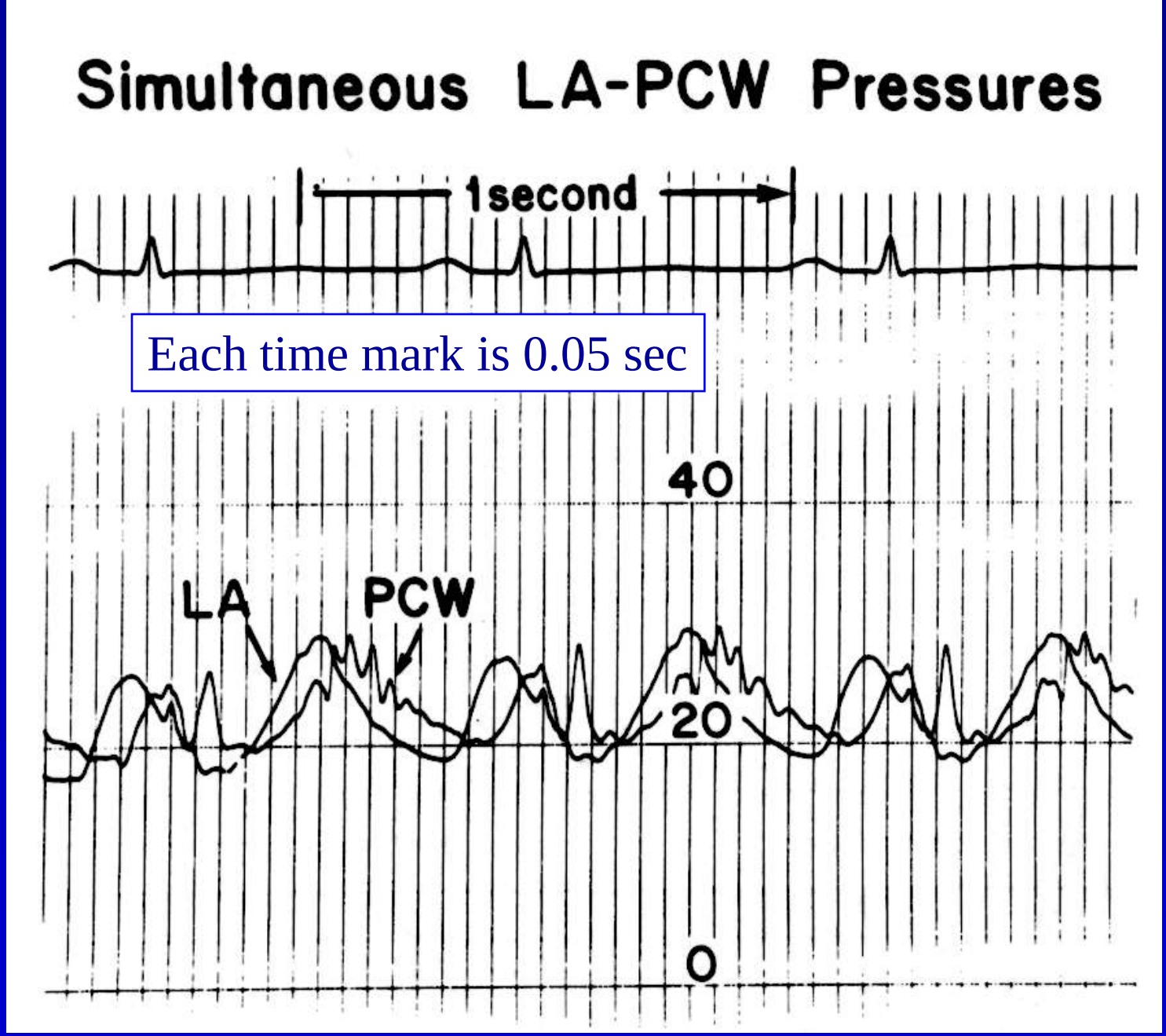
- Large regurgitant flow (mitral regurgitation)
- Stiff atrium (mitral stenosis, post cardiac surgery, infiltrative disease)
- High atrial volume (and distending pressure; example acute VSD, decompensated left heart failure)
- High heart rate*

Kern MJ et al. Chapter 17, Hurst, 11th ed. 2004; p. 520. *Kern, p. 96.

Right Heart Pressures with Goodale-Lubin

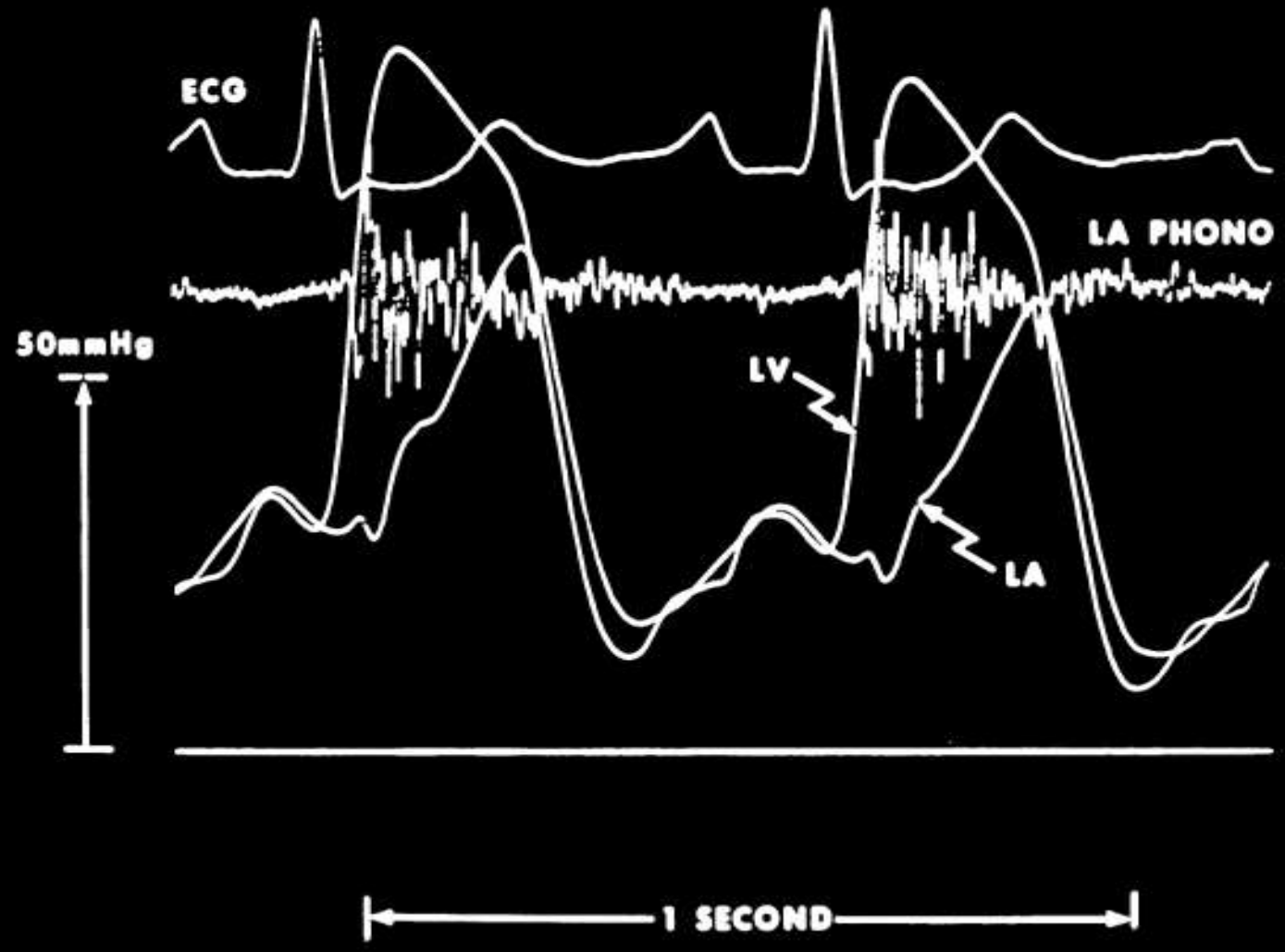


Grossman, 6th ed, 2000; p. 108



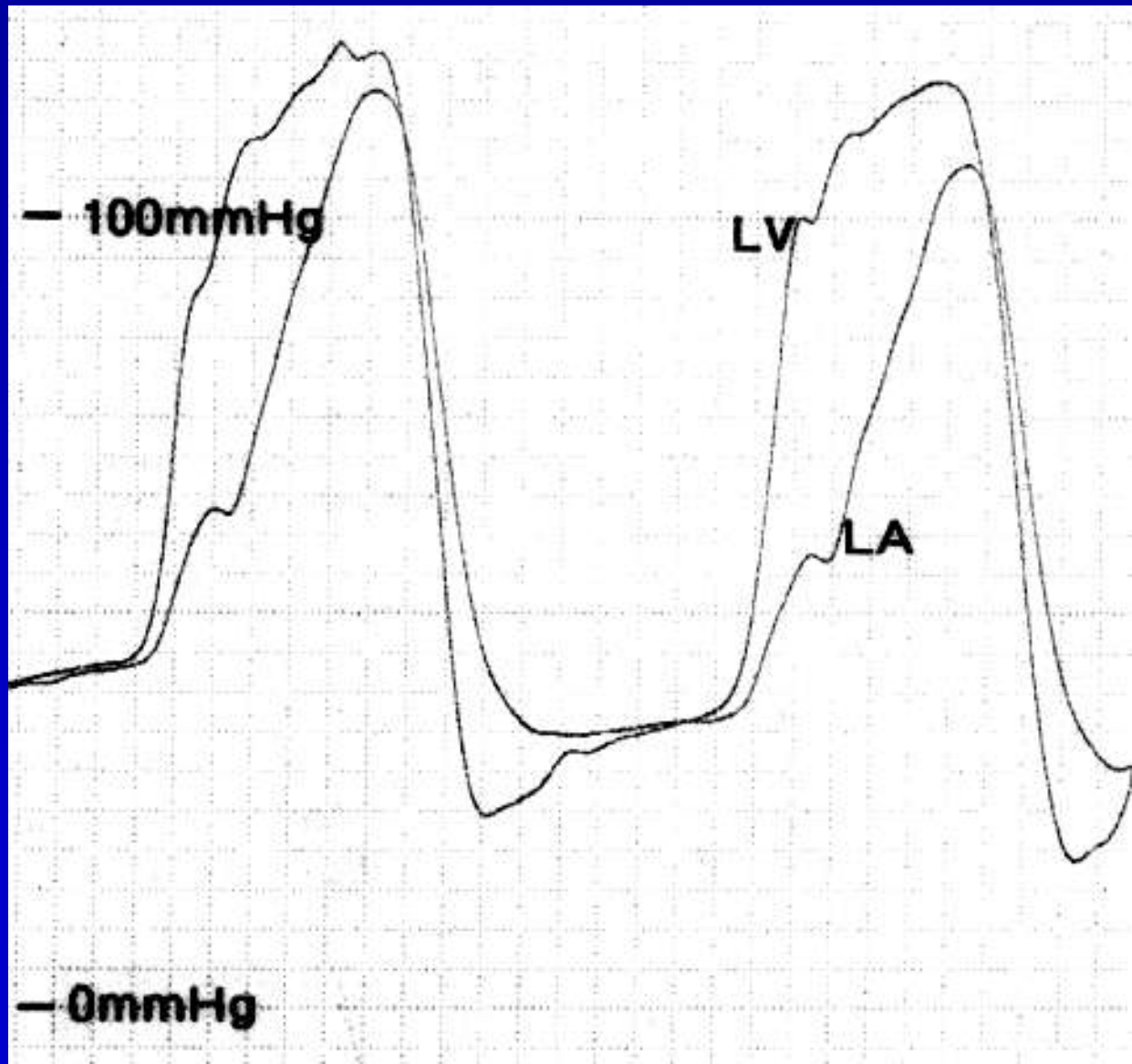
Grossman, 6th ed, 2000; p. 109 (from Lange RA et al. JACC 1989;13:825)

Acute Mitral Regurgitation



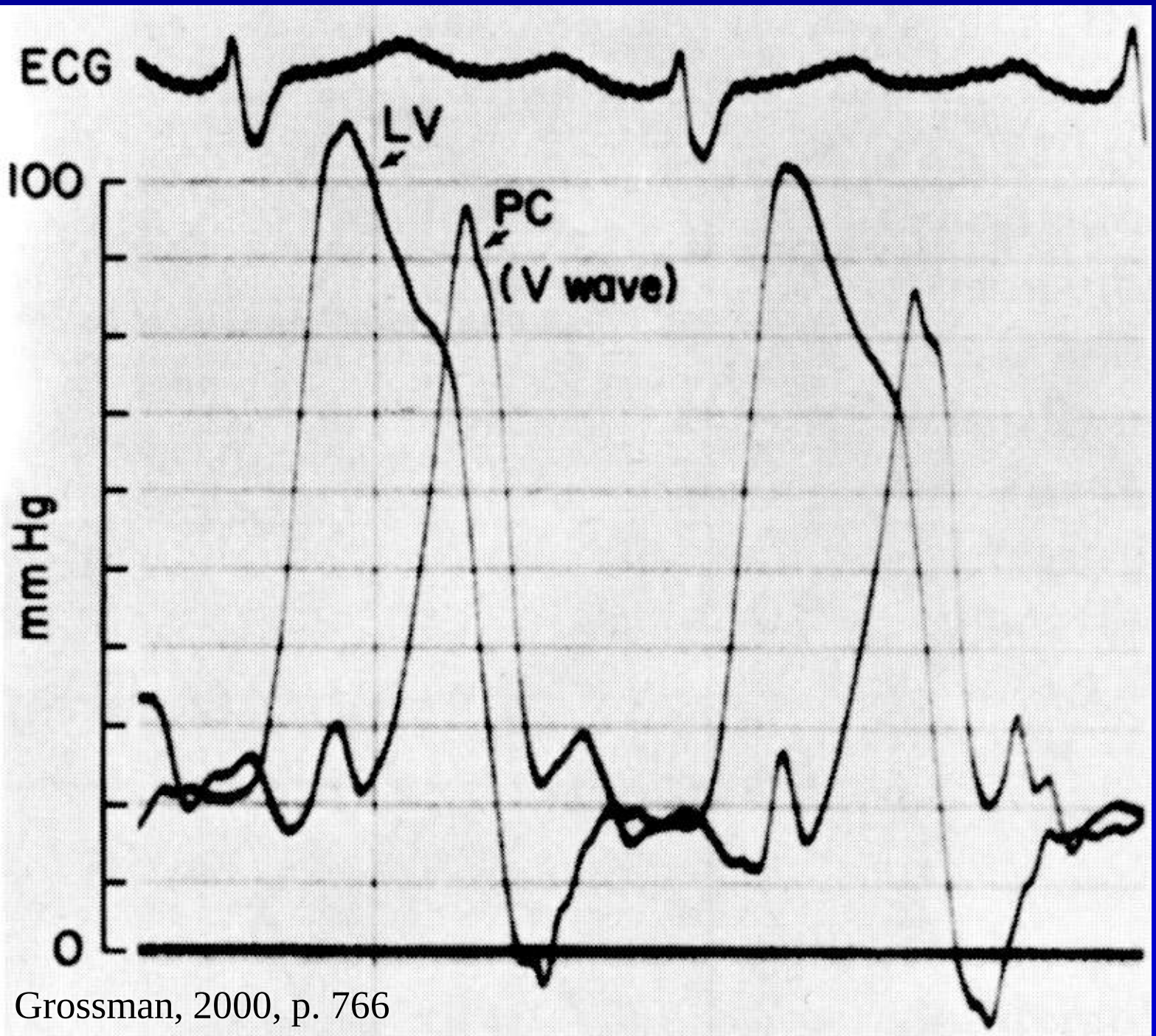
From the Brooke Army Medical Center Hemodynamic Collection

Acute Mitral Regurgitation



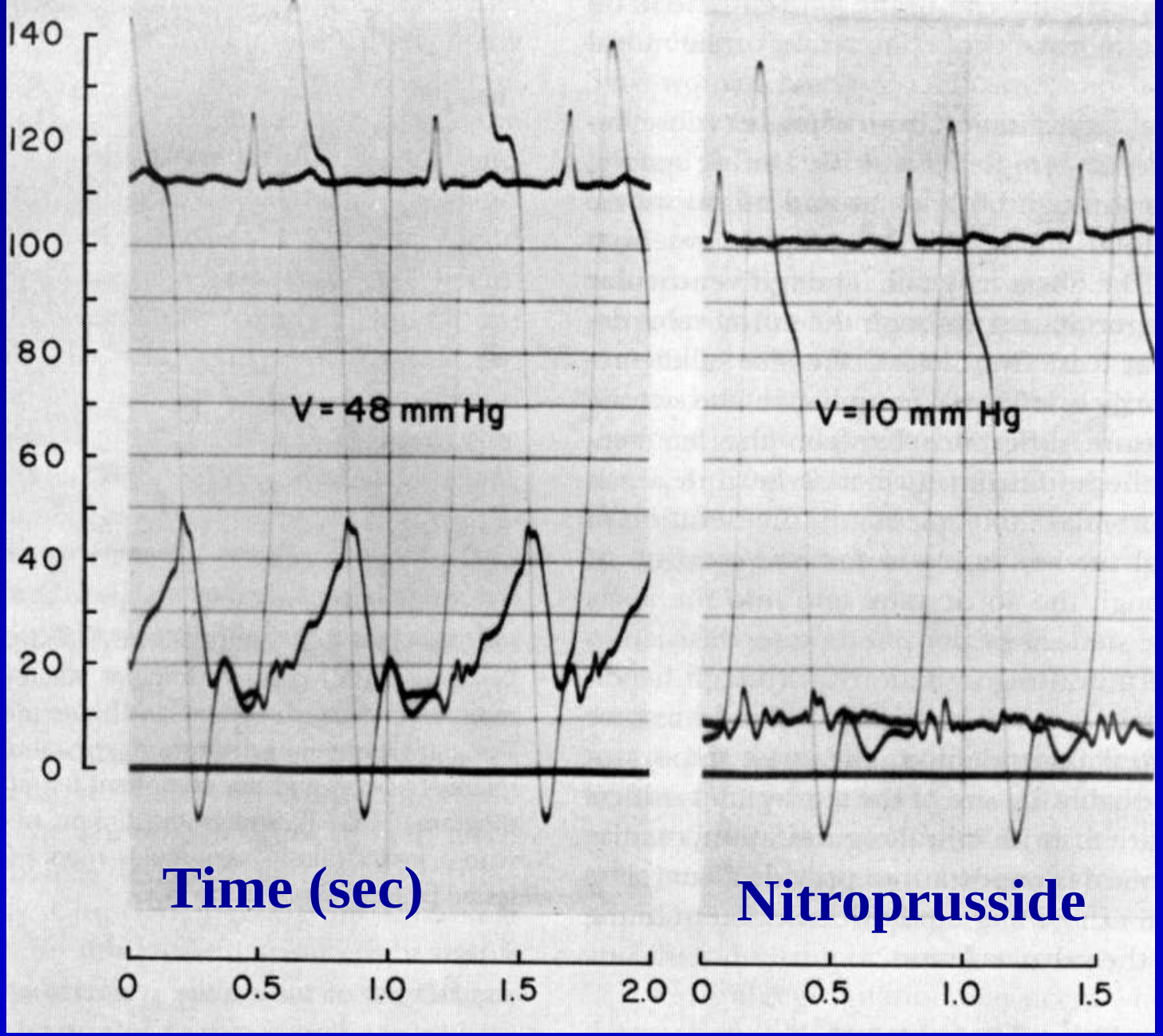
Hurst, 2004, p.1689

Ruptured Chordae Tendineae



Grossman, 2000, p. 766

Effect of Afterload reduction on V wave



Grossman, 6th ed. 2000, p. 767

Acute MR with Balloon Valvuloplasty for MS

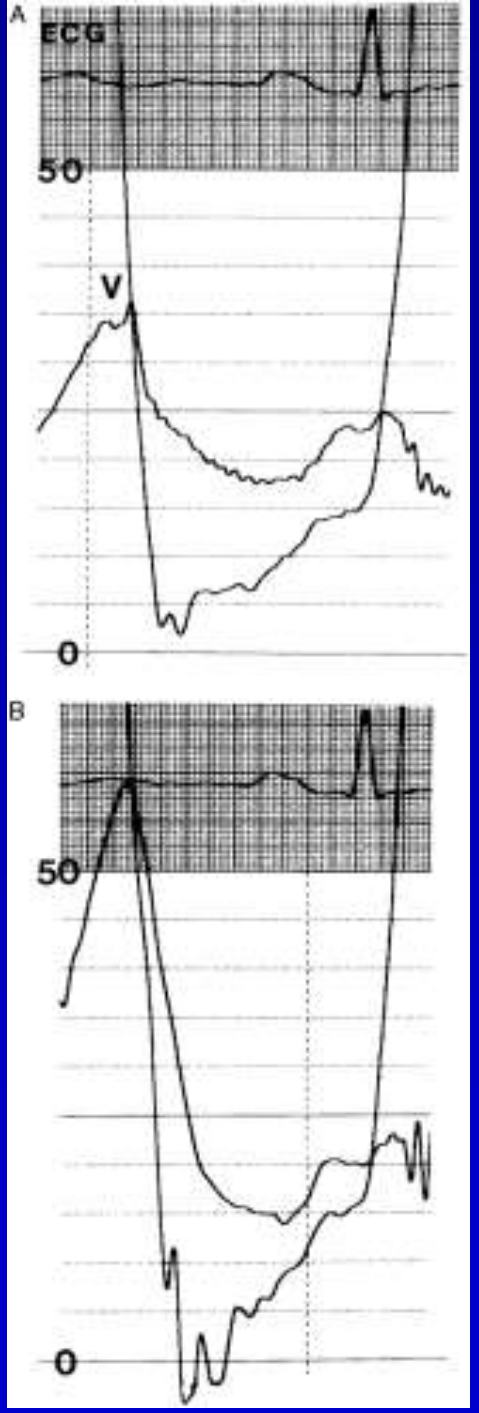
Poor LA compliance associated with large V wave

Severe MR after valvuloplasty (i.e. acute) was associated with increase in V wave (10 mmHg for severe)

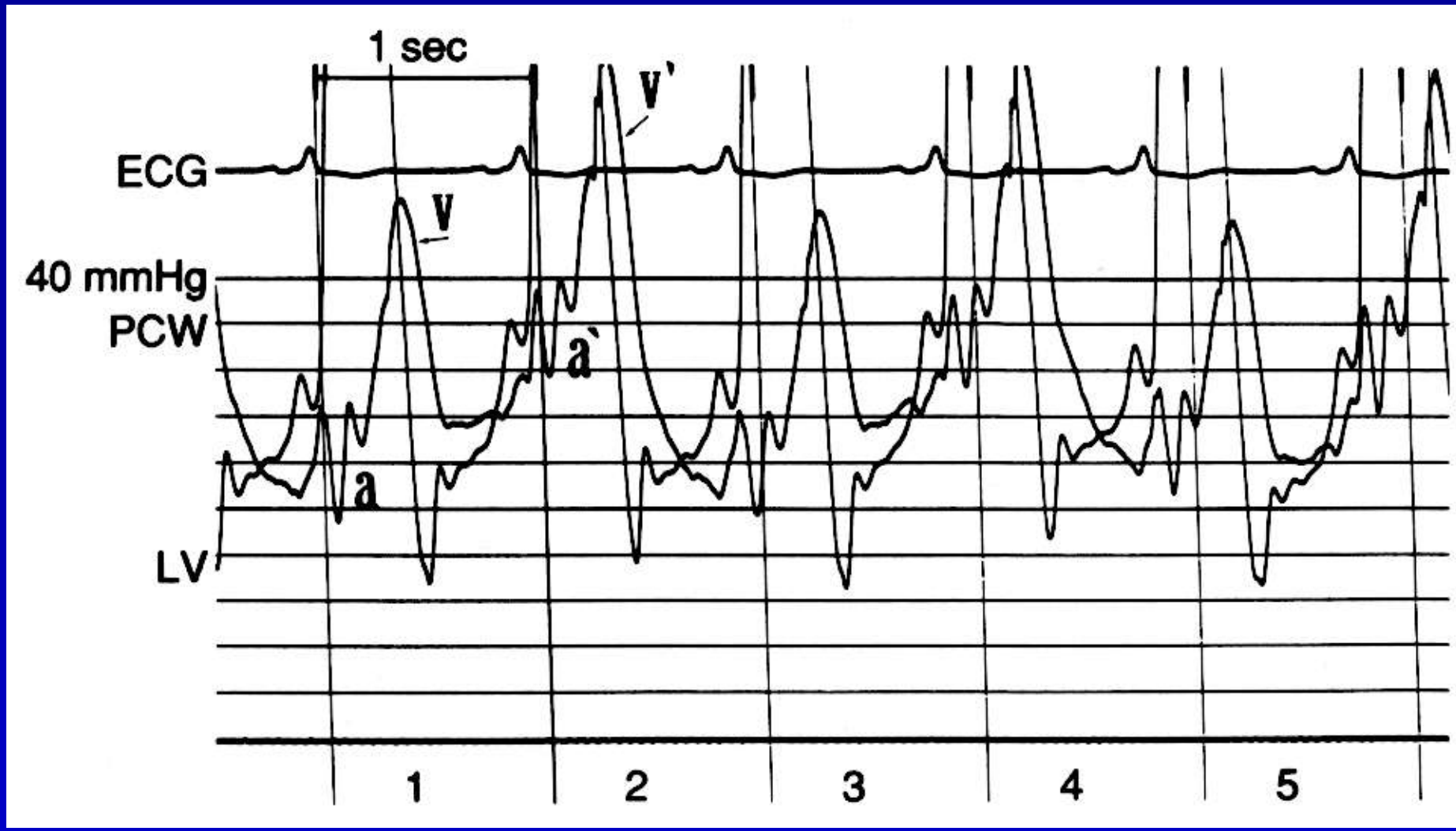
Successful valvuloplasty associated with decrease in V wave (9 mmHg)

Pre: 30 mmHg

Post: 60 mmHg

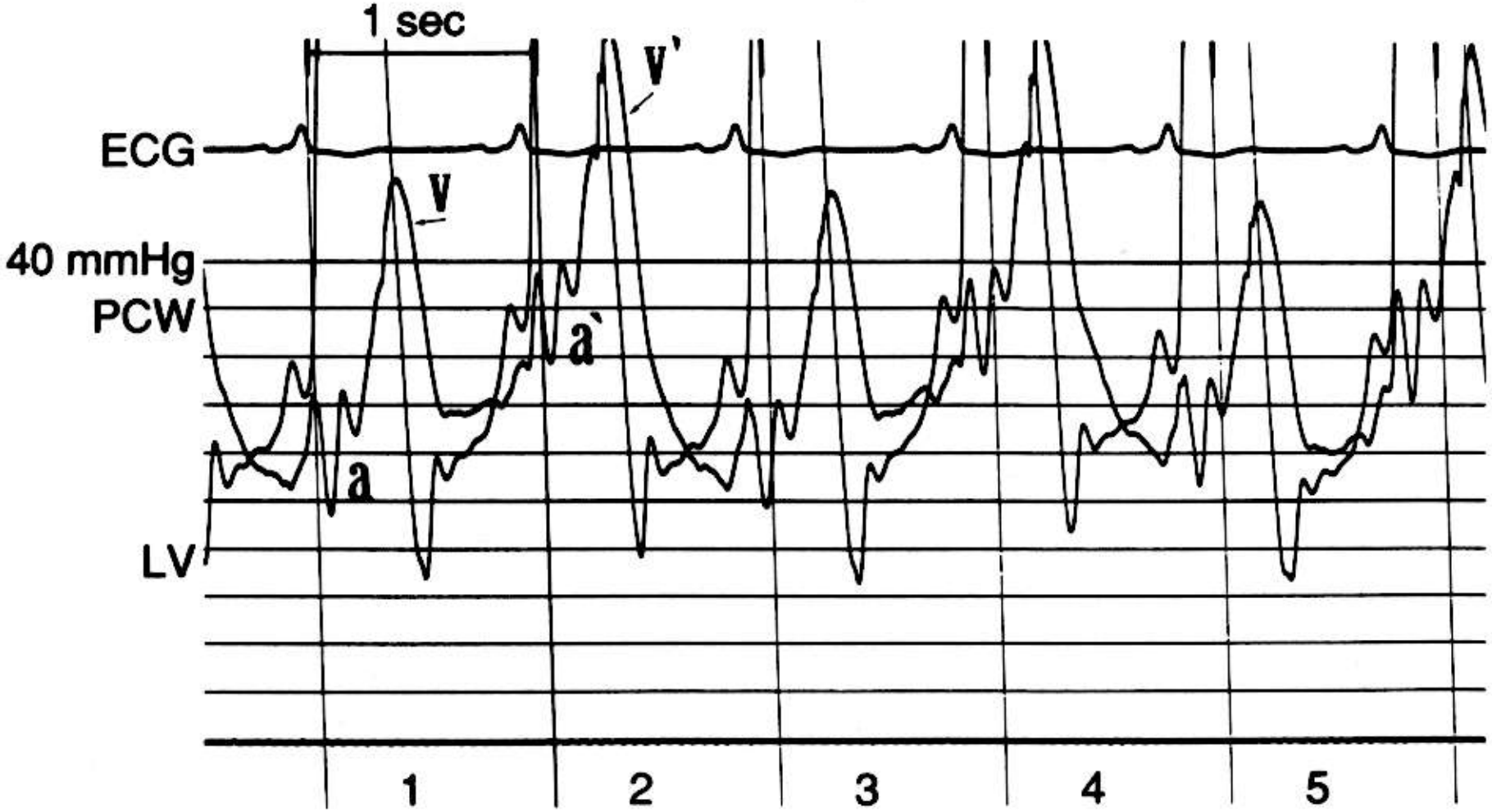


Wang A et al, Am J Cardiol. 1998;82:1388.



Why the large V wave?

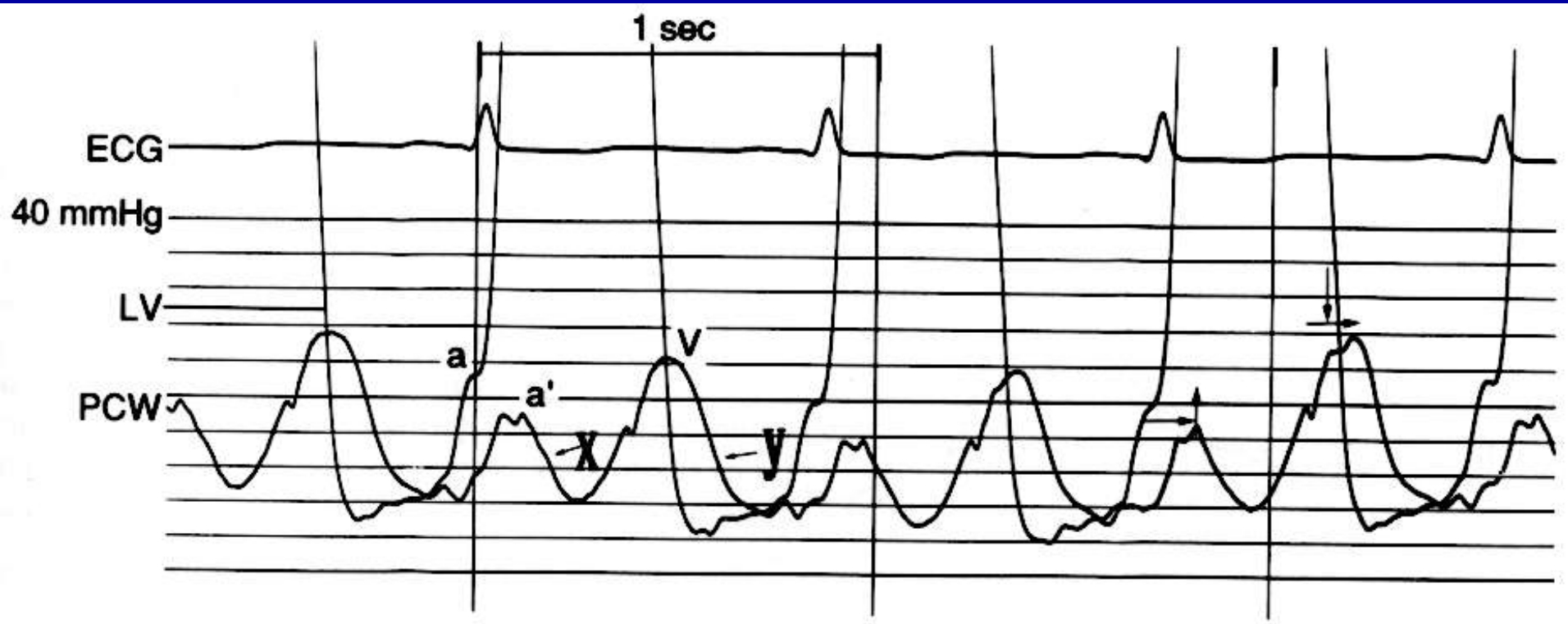
Kern, 1999, p. 94



Large V wave. V wave alternans. Advanced CHF.
Also had pulsus alternans of aortic pressure.
No mention of MR. 69 year old man.

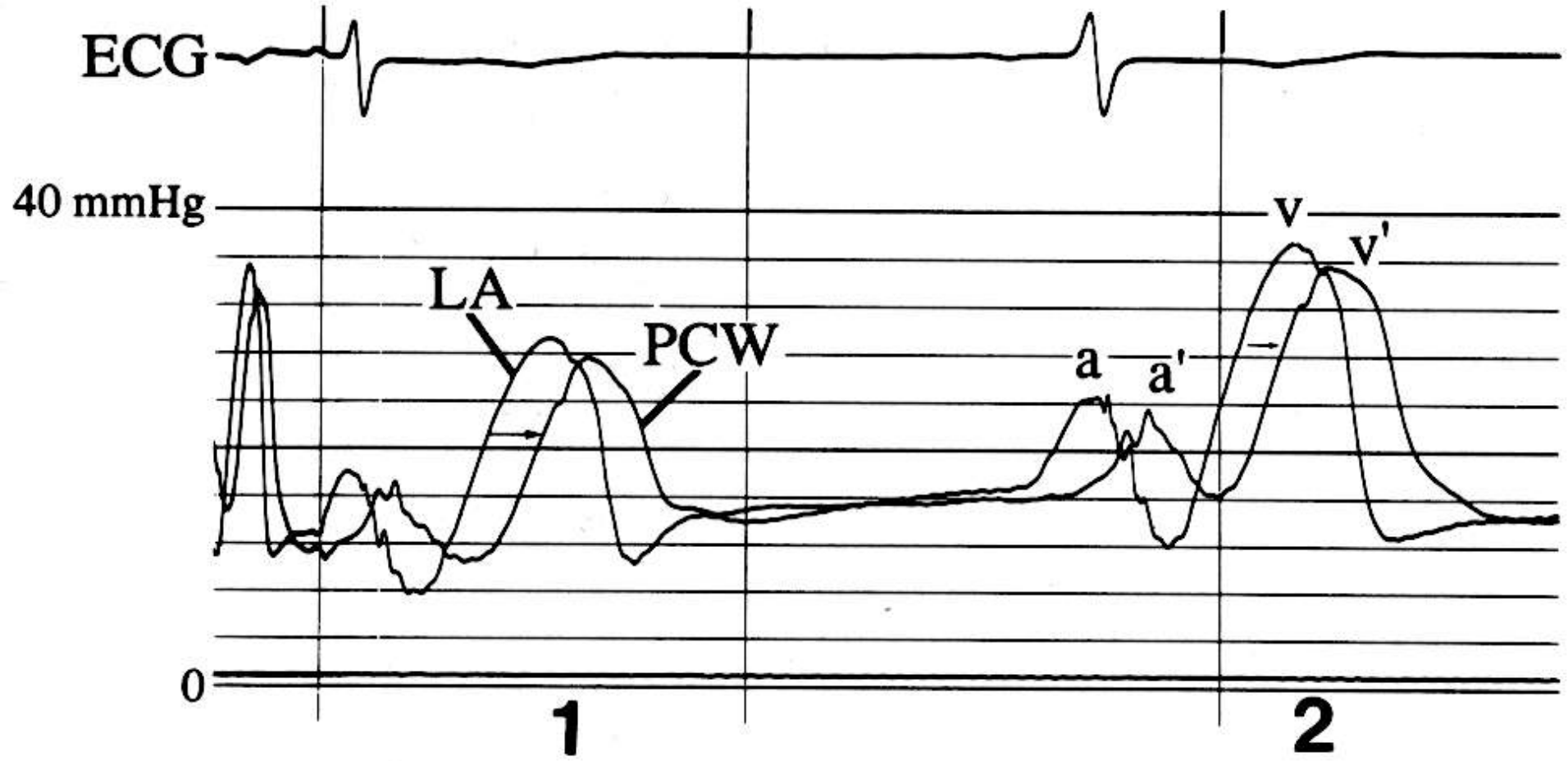
Kern, 1999, p. 94

Normal PCW Pressure



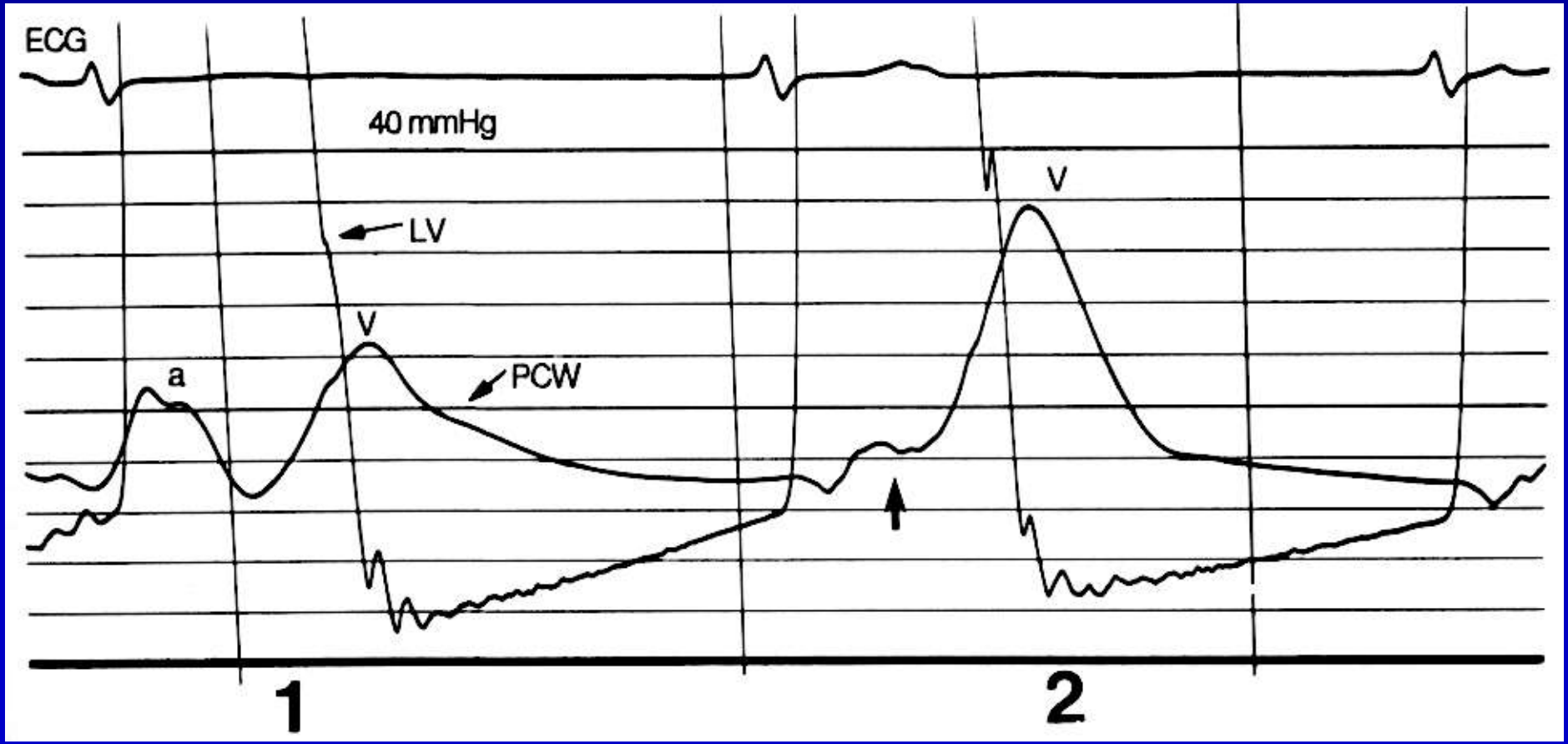
Kern, 1999, p. 95

Comparison of LA and PCW



Kern, 1999, p. 95

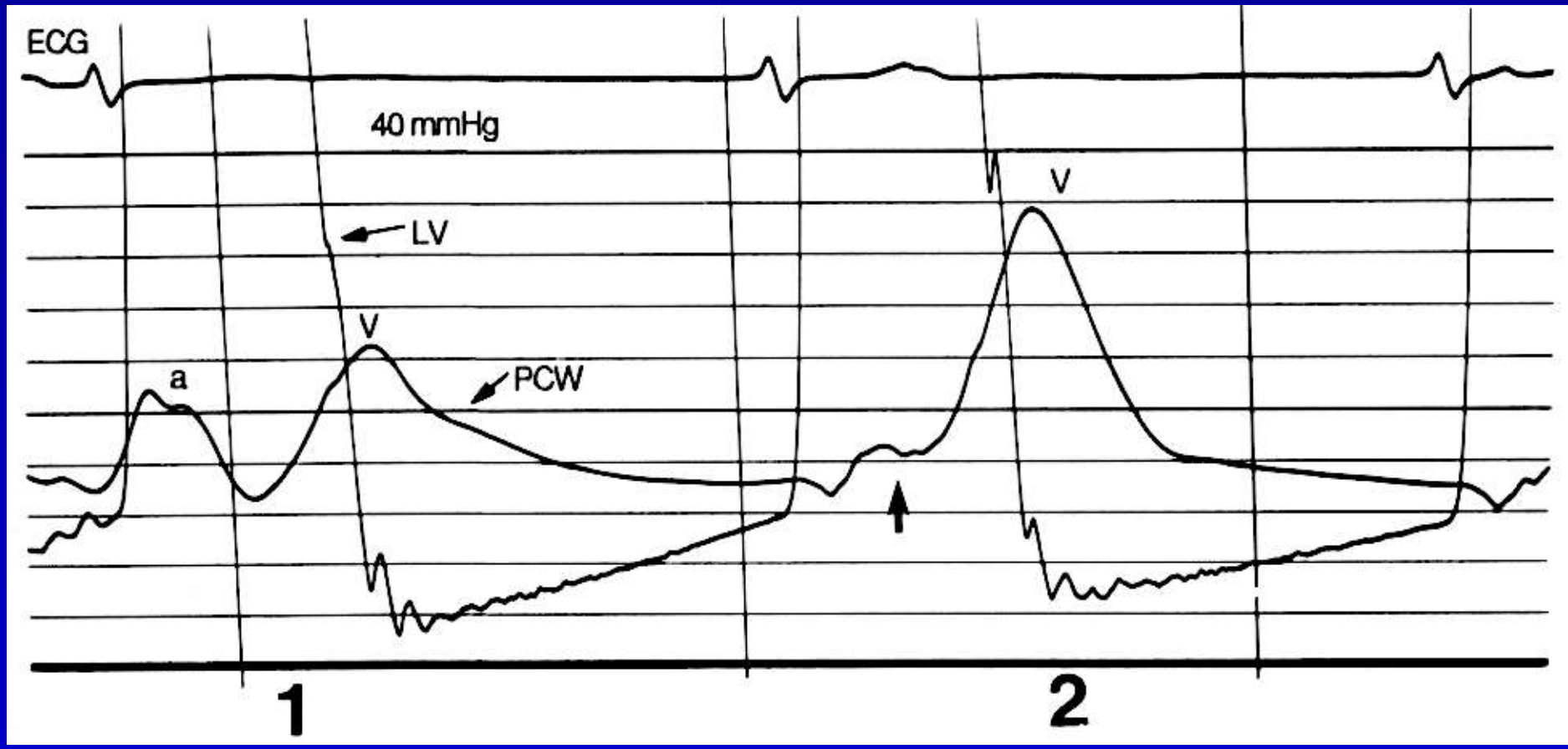
V wave in Mitral Stenosis



Patient with combined MS and MR pre valvuloplasty

Kern, 1999, p. 97

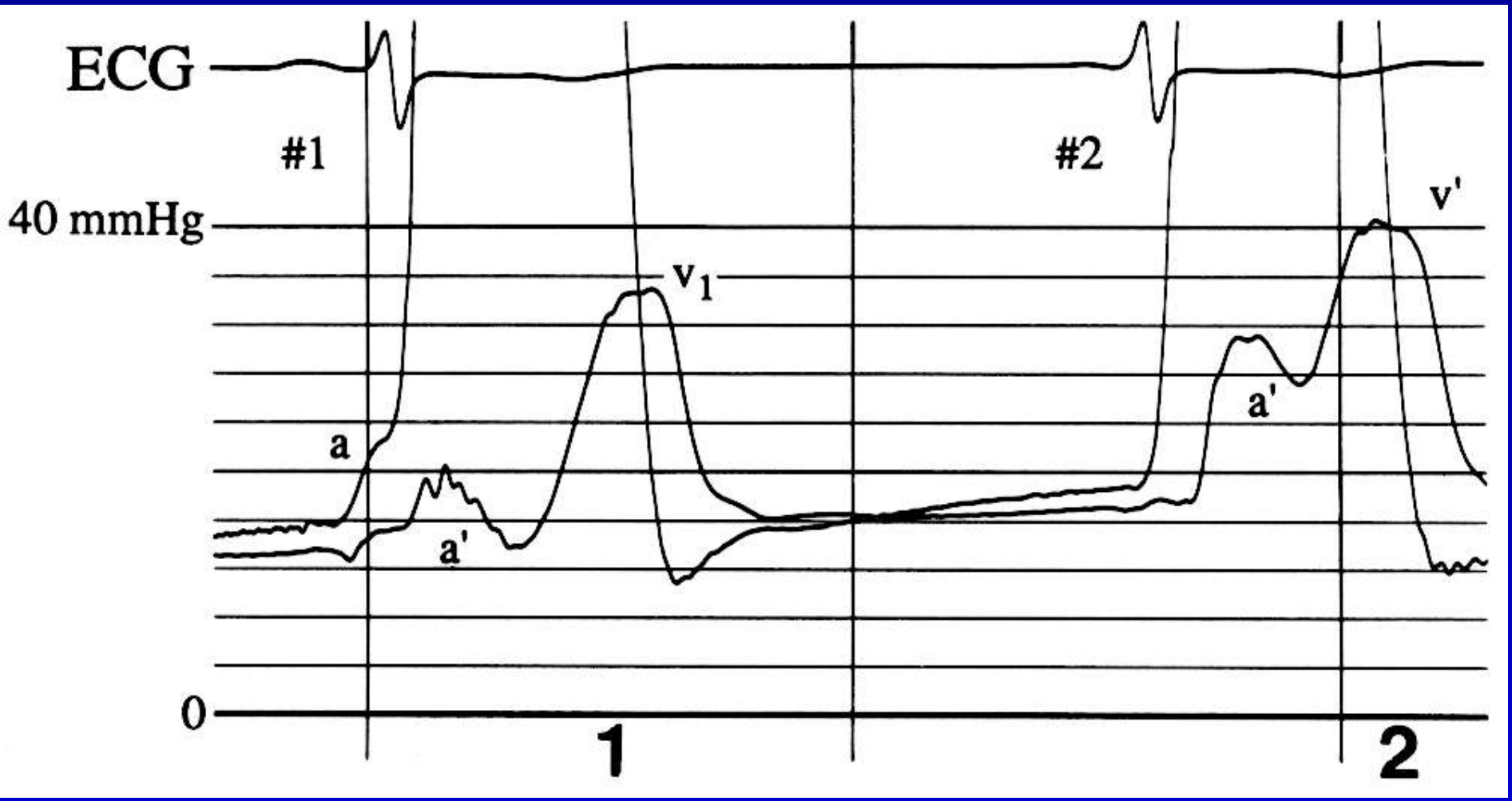
Note the P waves



Beat 2 has no preceding P wave or A wave.
The big V wave is actually a cannon A wave.

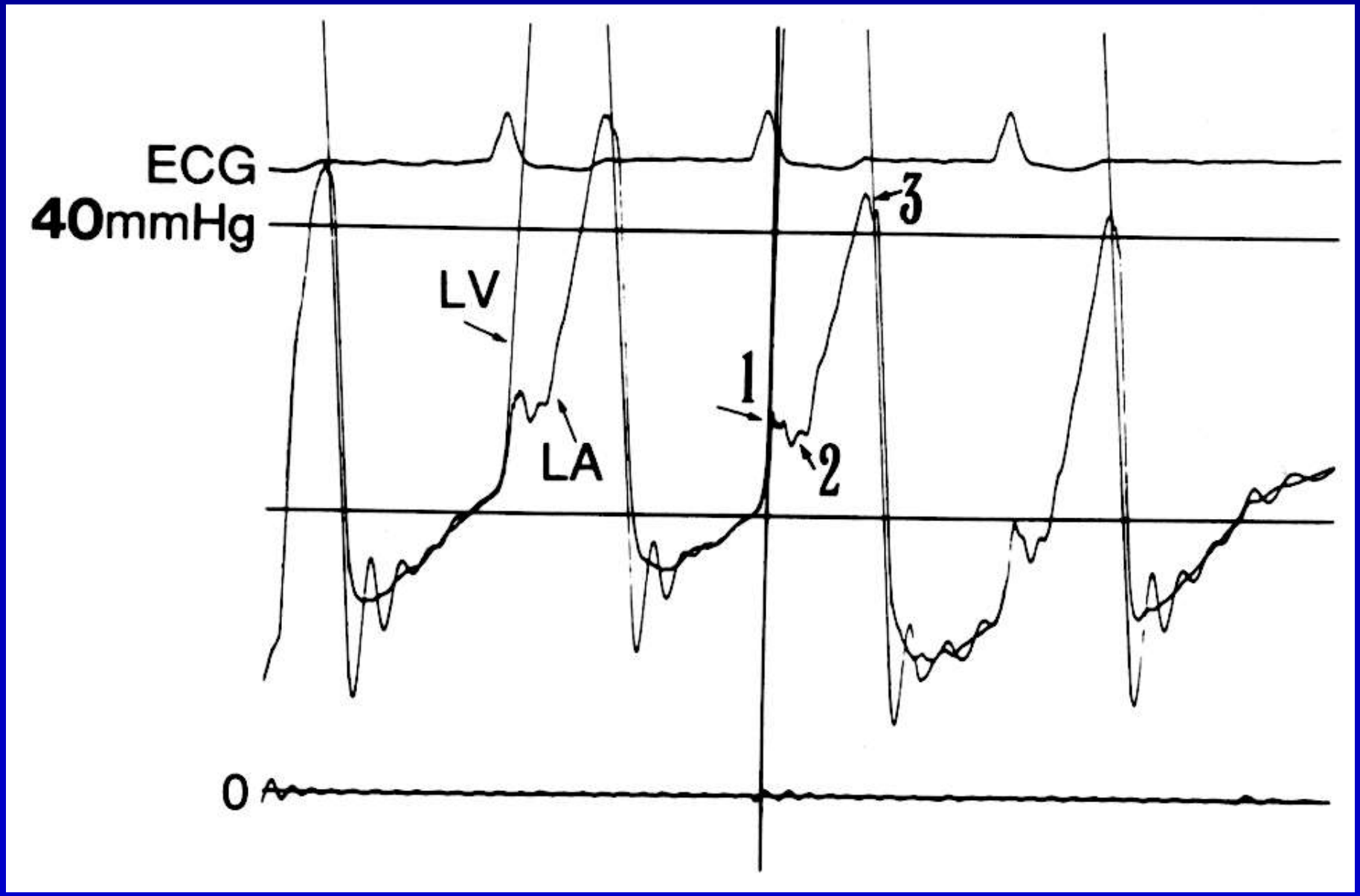
Kern, 1999, p. 97

Note the large V wave



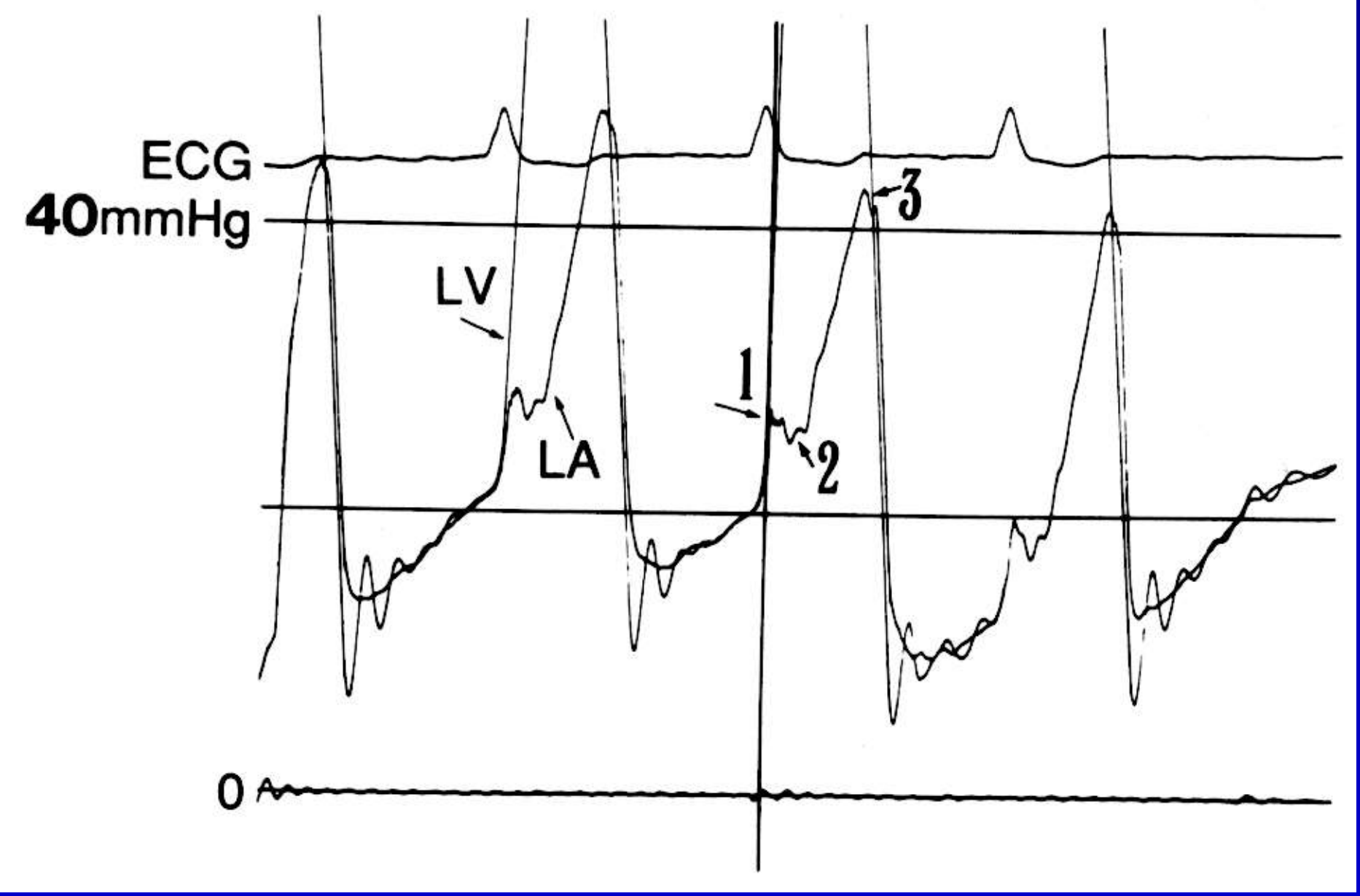
Beat 2 has no preceding P wave and has a large A wave. There is no MR. The larger V on beat 2 is passive.

Kern, 1999, p. 98



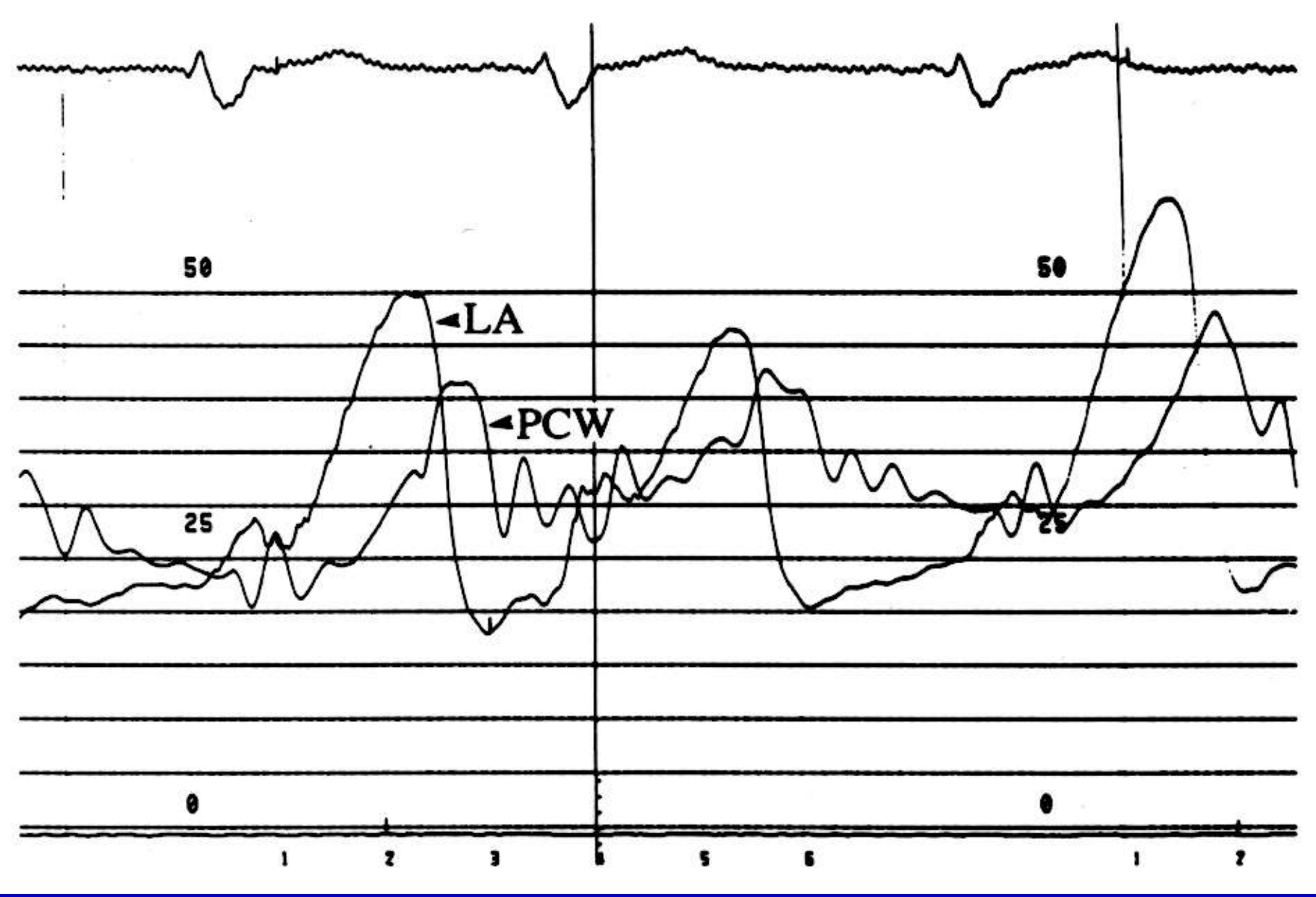
Prosthetic MV, new fatigue and systolic murmur

Kern, 1999, p. 98



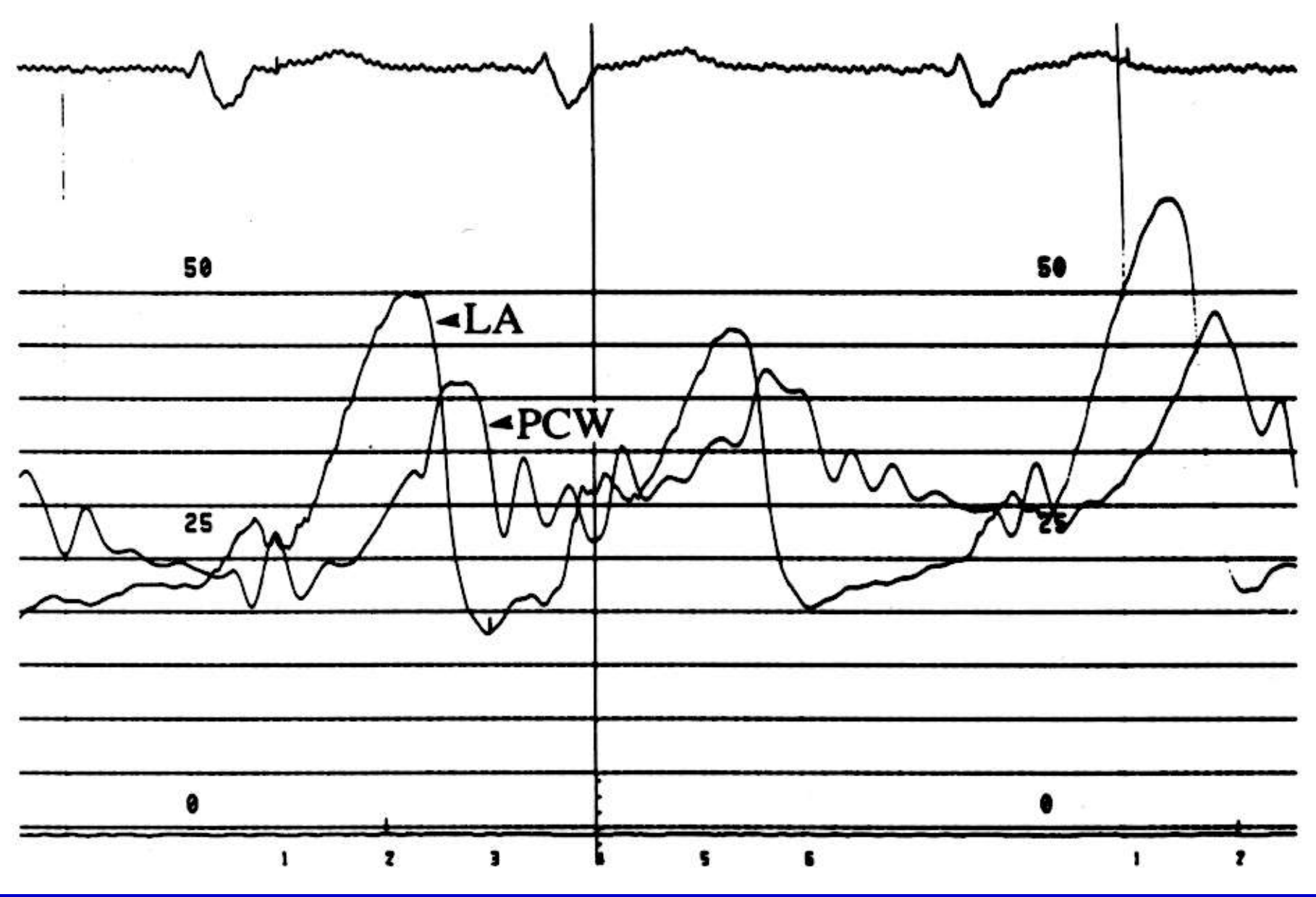
Label the waves. Is there regurgitation? Stenosis?

Kern, 1999, p. 98



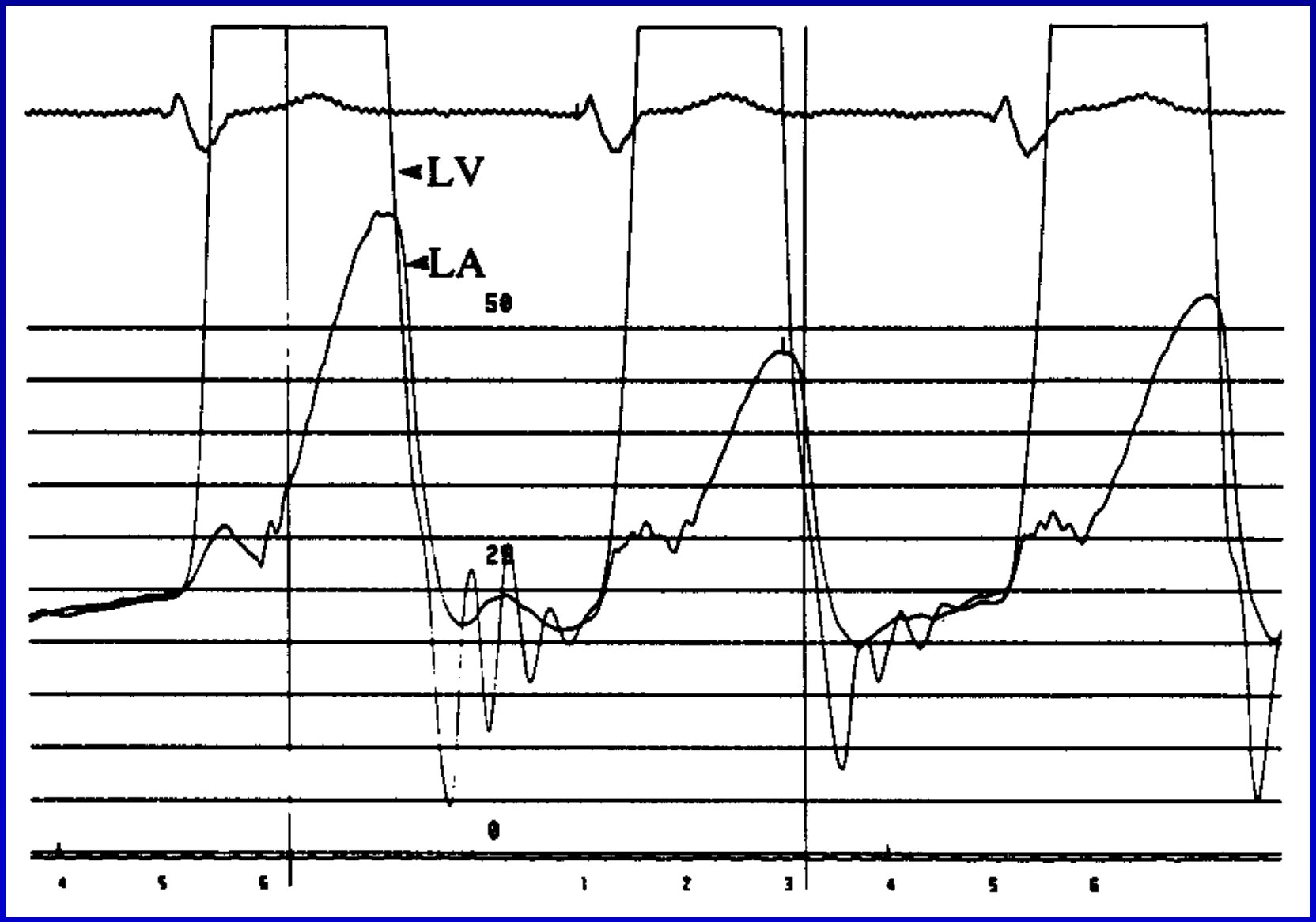
Simultaneous LA and PCW. Patient with MV Commissurotomy and MR and Progressive fatigue

Kern, 1999, p. 99



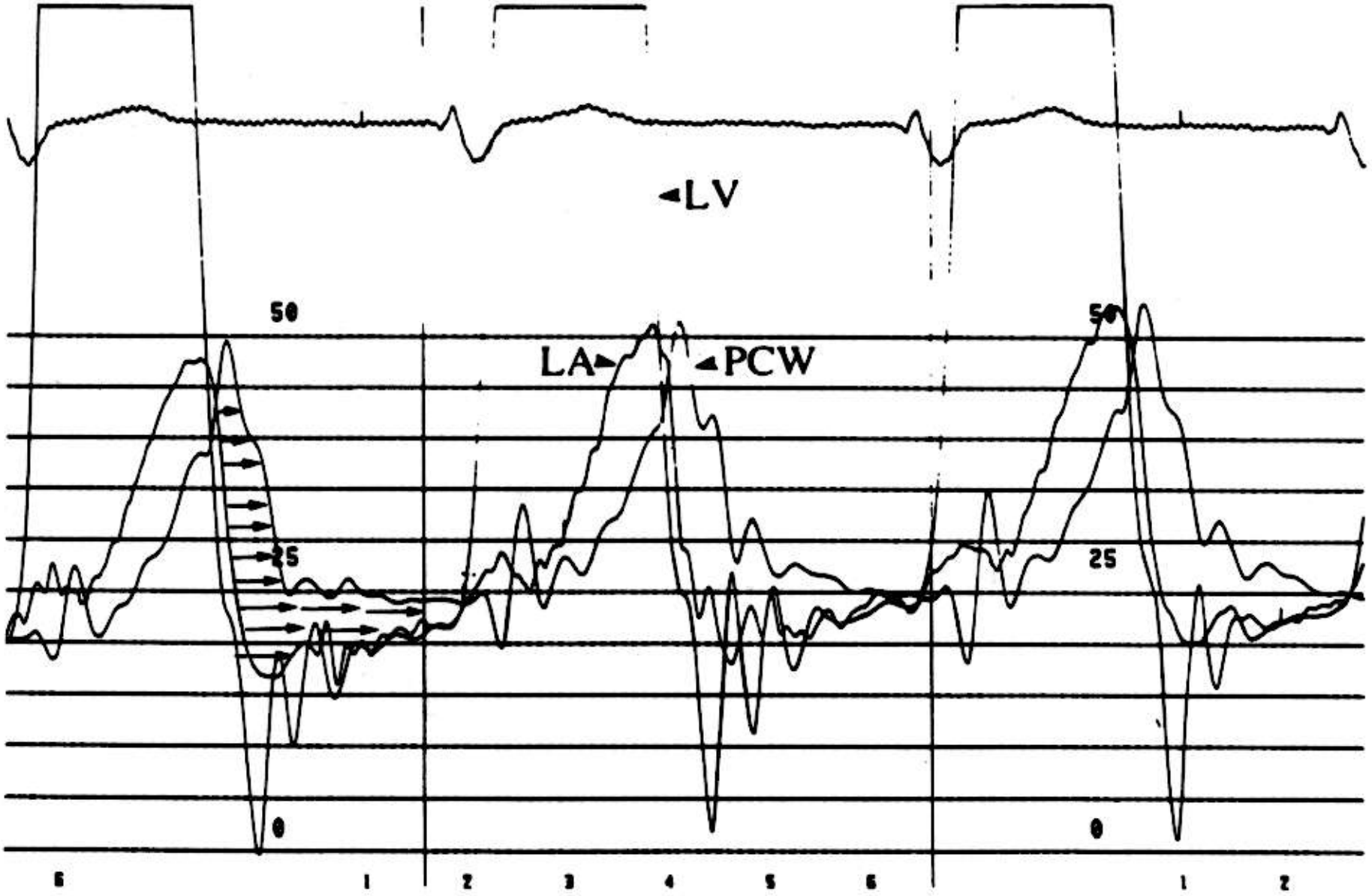
Note higher LA systolic and earlier occurrence and similar mean pressures, and slower PCW Y descent

Kern, 1999, p. 99



Simultaneous LA and LV. Same Patient with MV Commisurotomy and MR and Progressive fatigue. Is there MS?

Kern, 1999, p. 99

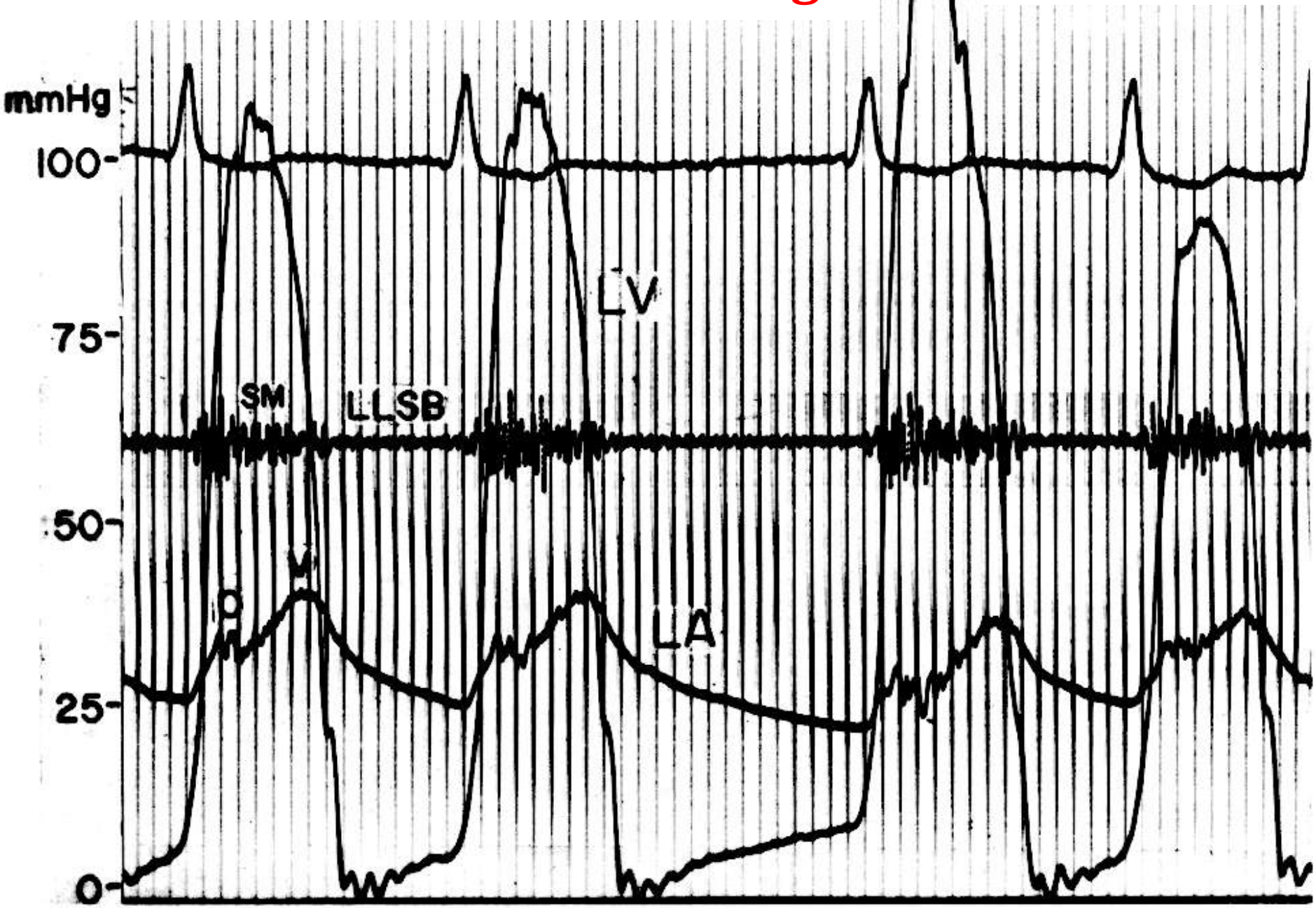


Arrows denote erroneous gradient if PCW used.

Kern, 1999, p. 99

LA and LV and Phono Tracings

Criley JM and Ross RS, Tampa Tracings, 1971



LA and LV and Phono Tracings

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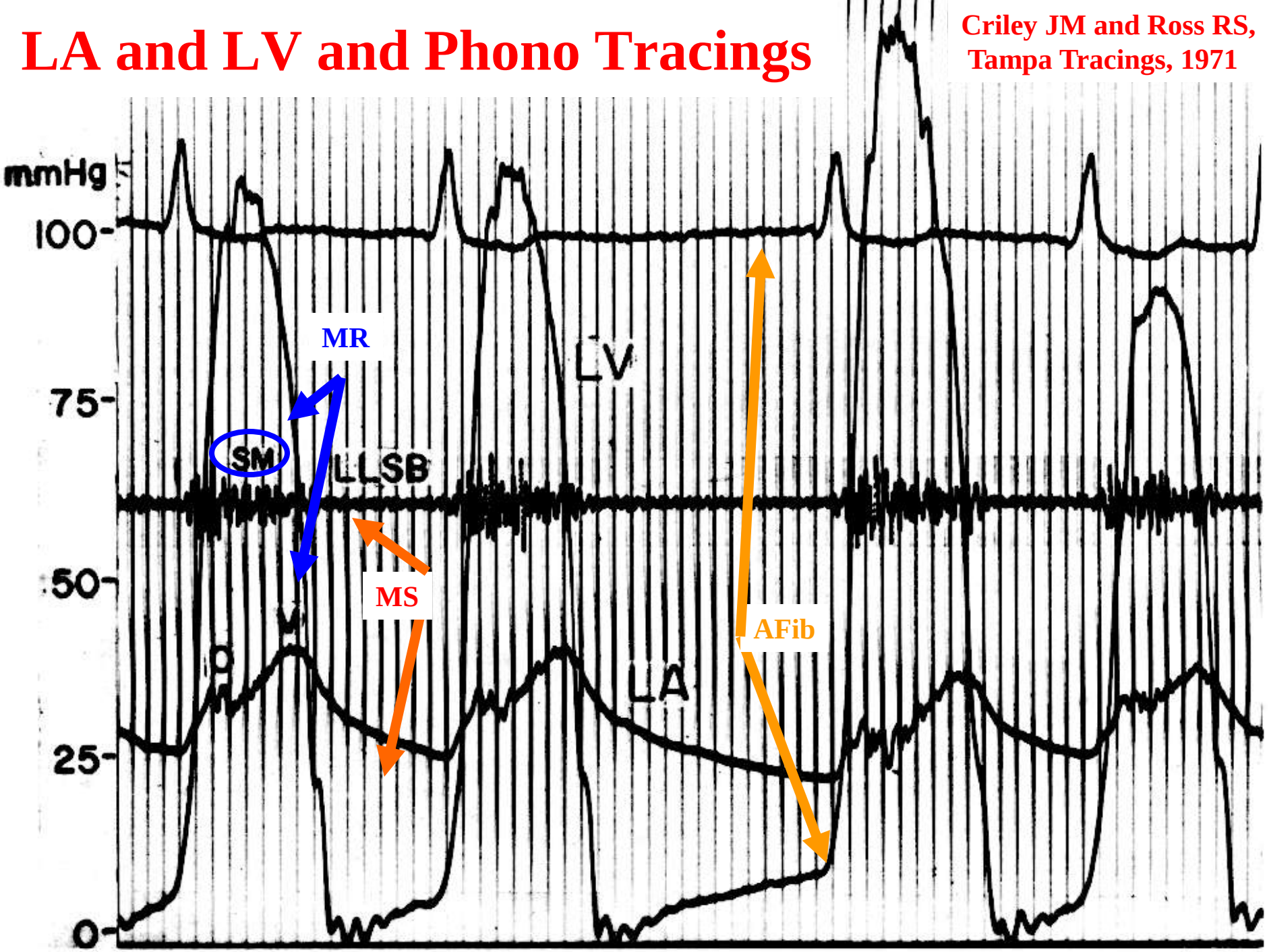
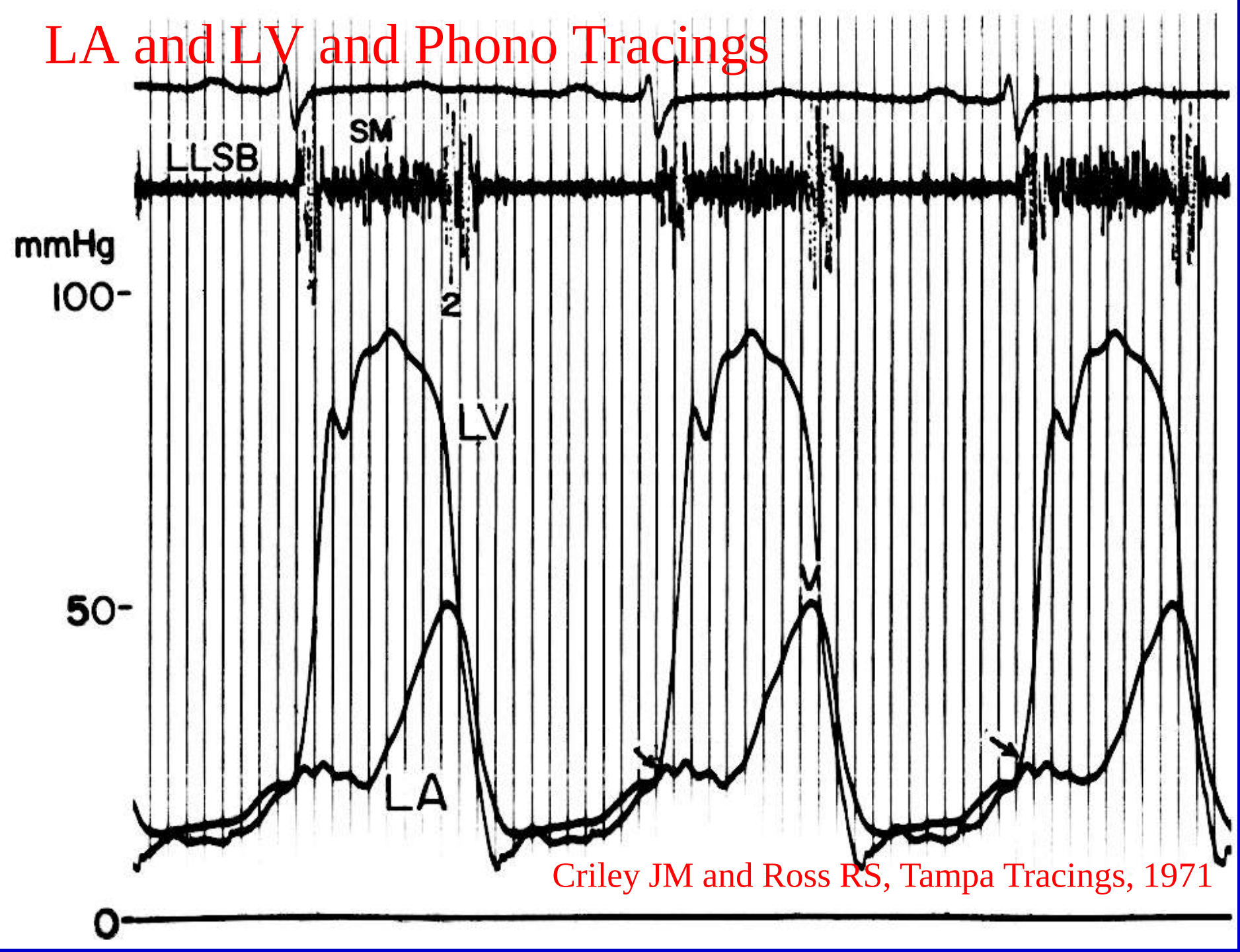


LA and LV and Phono Tracings



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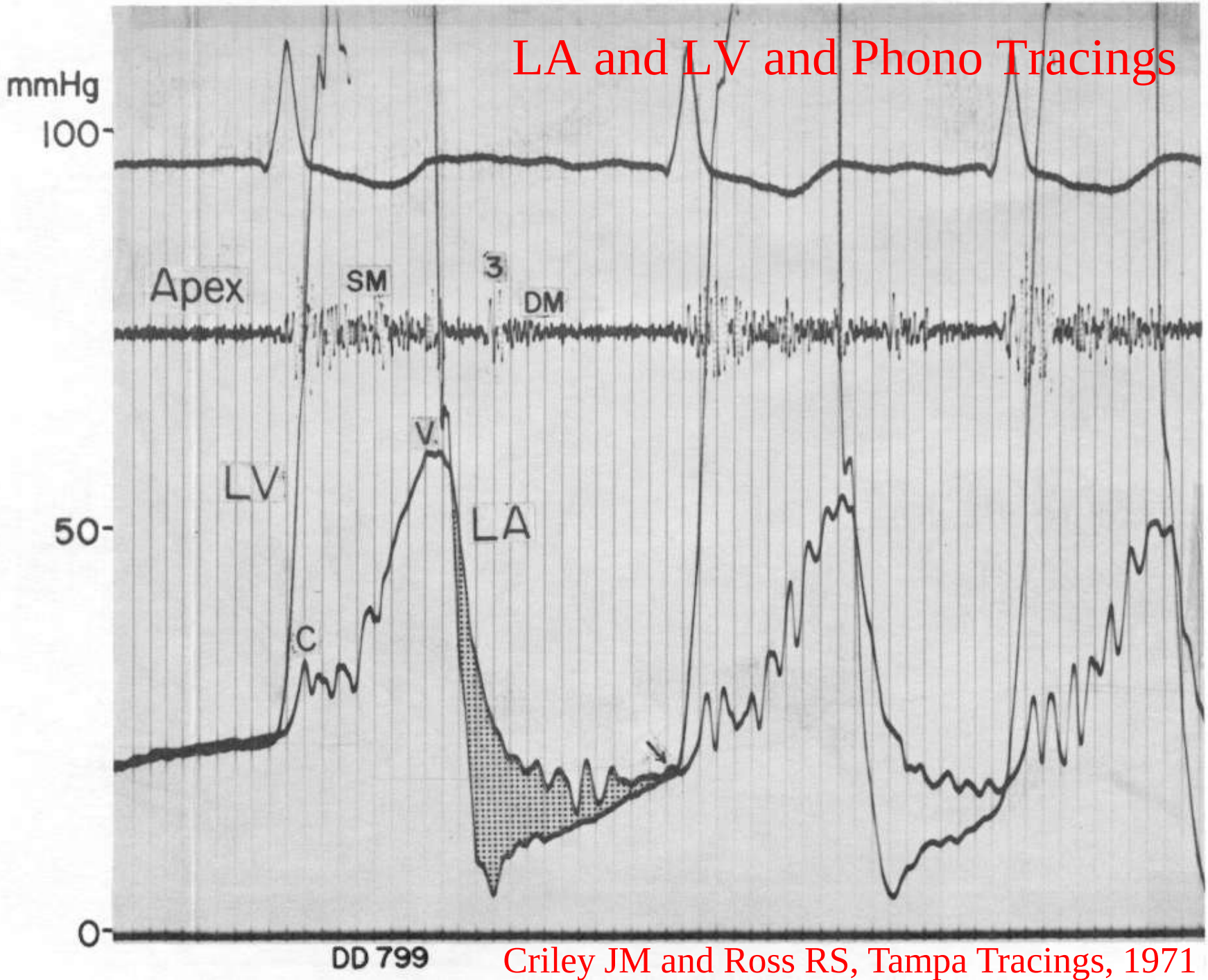
LA and LV and Phono Tracings



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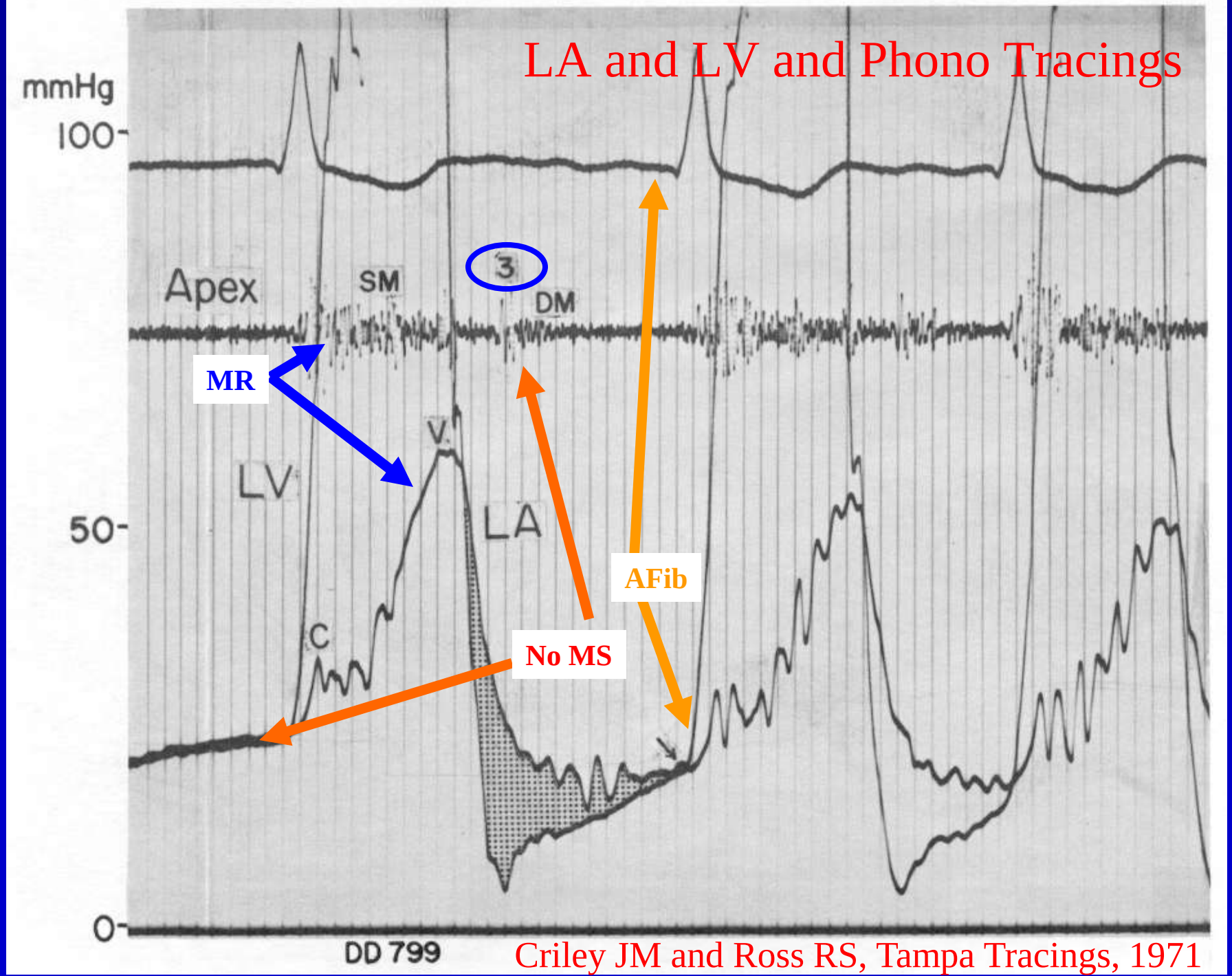
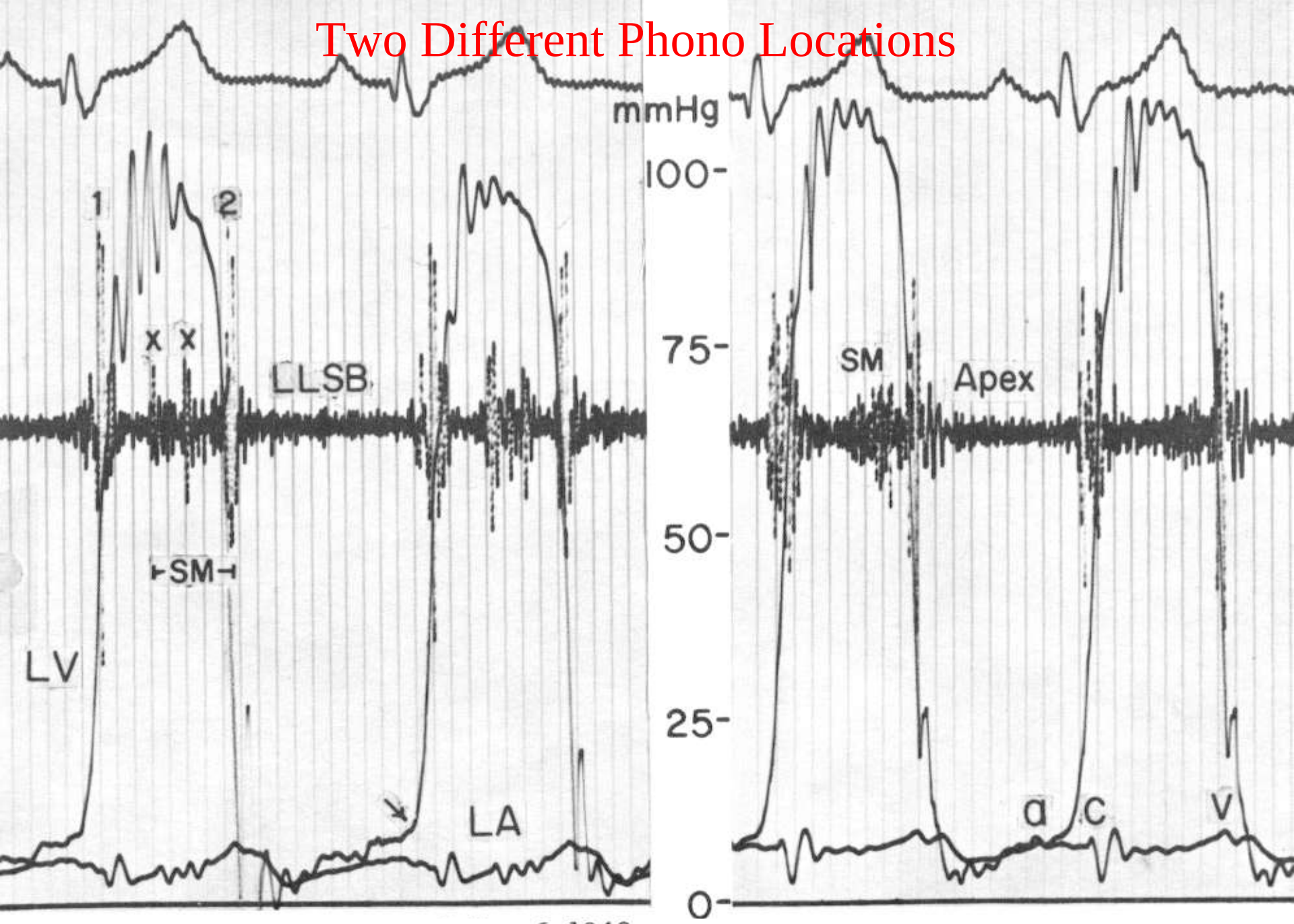

LA and LV and Phono Tracings
mmHg
100
50
0
Apex
SM
3
DM
MR
LV
V
LA
C
AFib
No MS
DD 799
Criley JM and Ross RS, Tampa Tracings, 1971

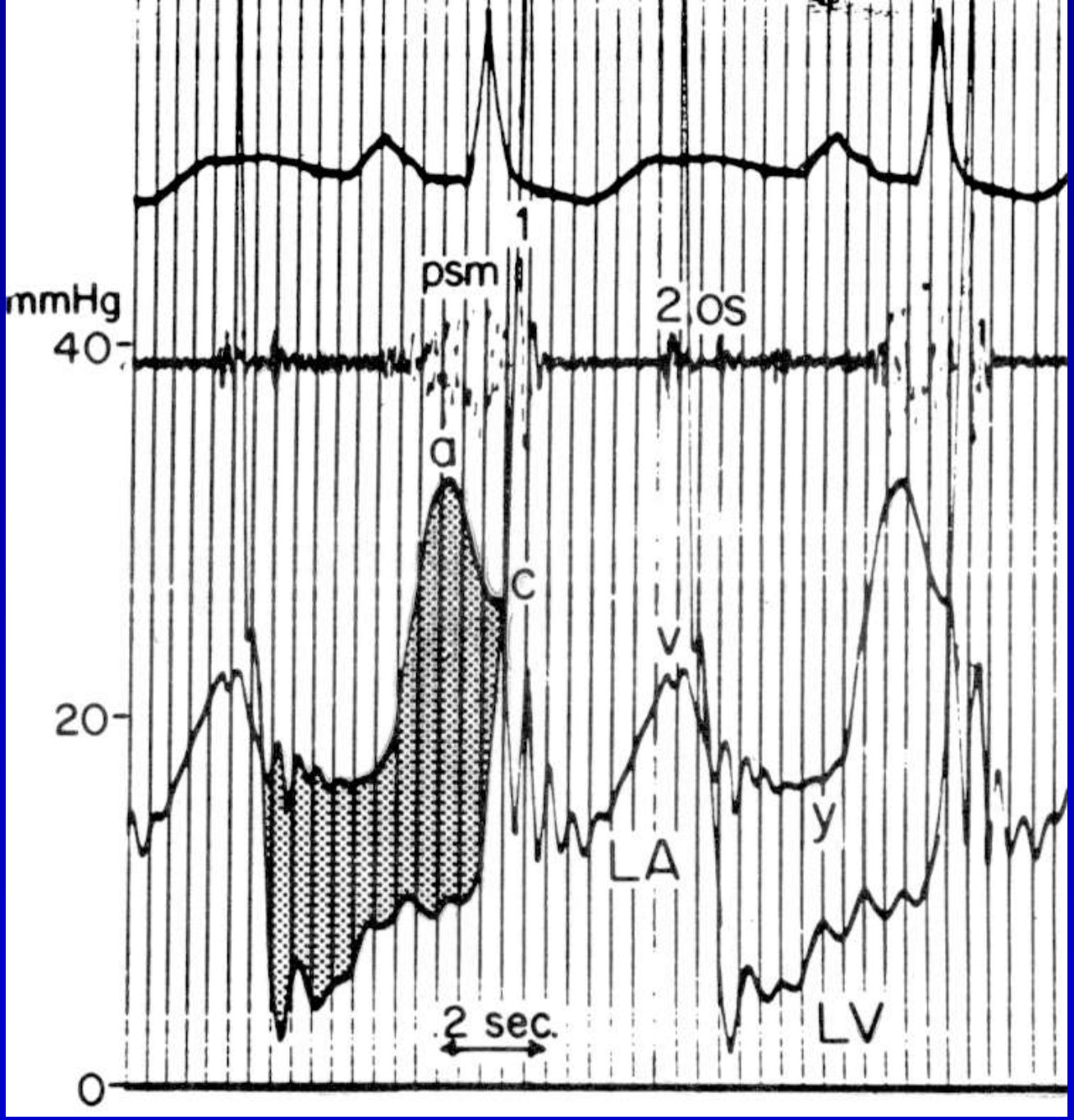
Two Different Phono Locations



Significant MR and normal V wave

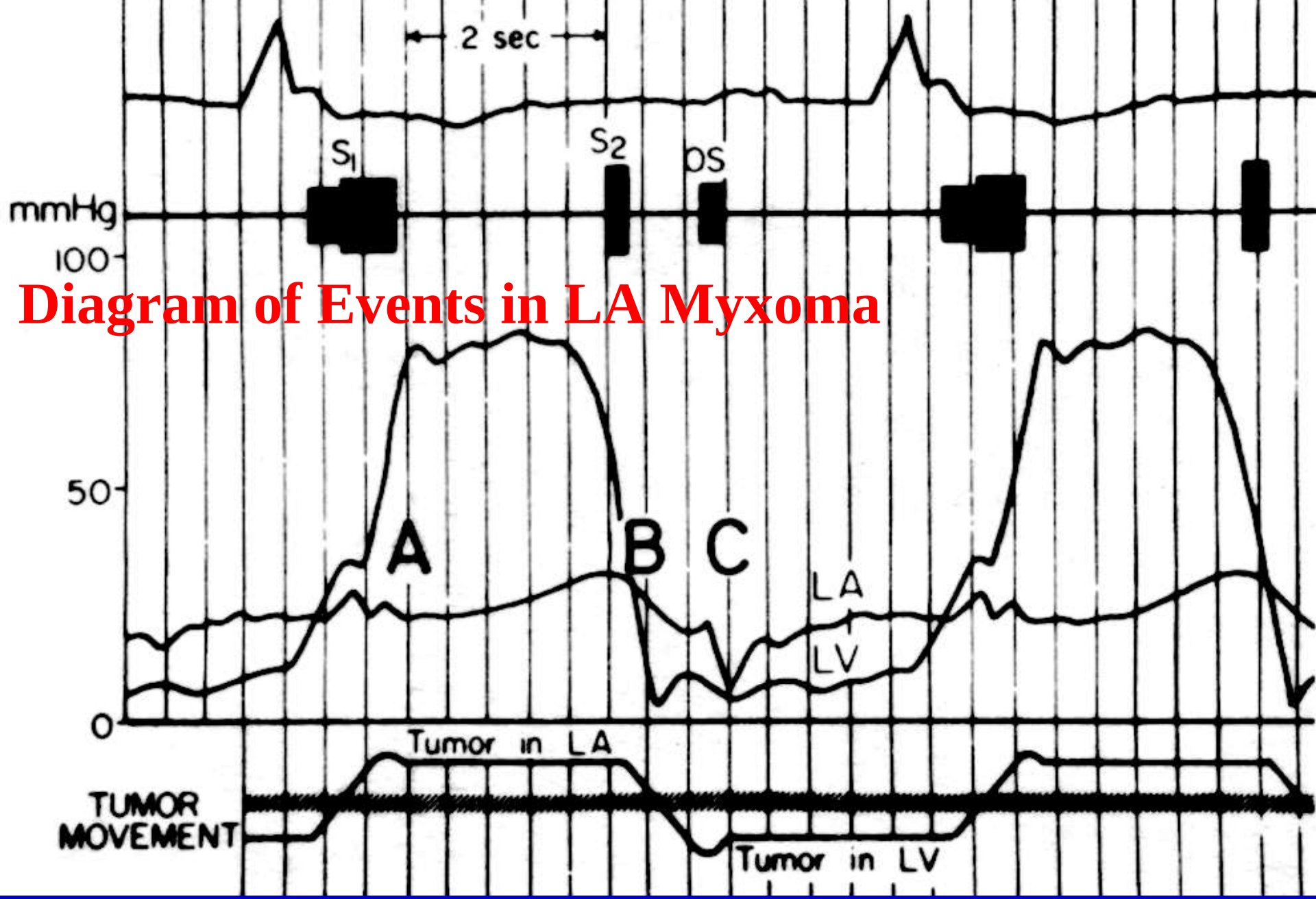
Criley JM and Ross RS, Tampa Tracings, 1971

Mitral Stenosis



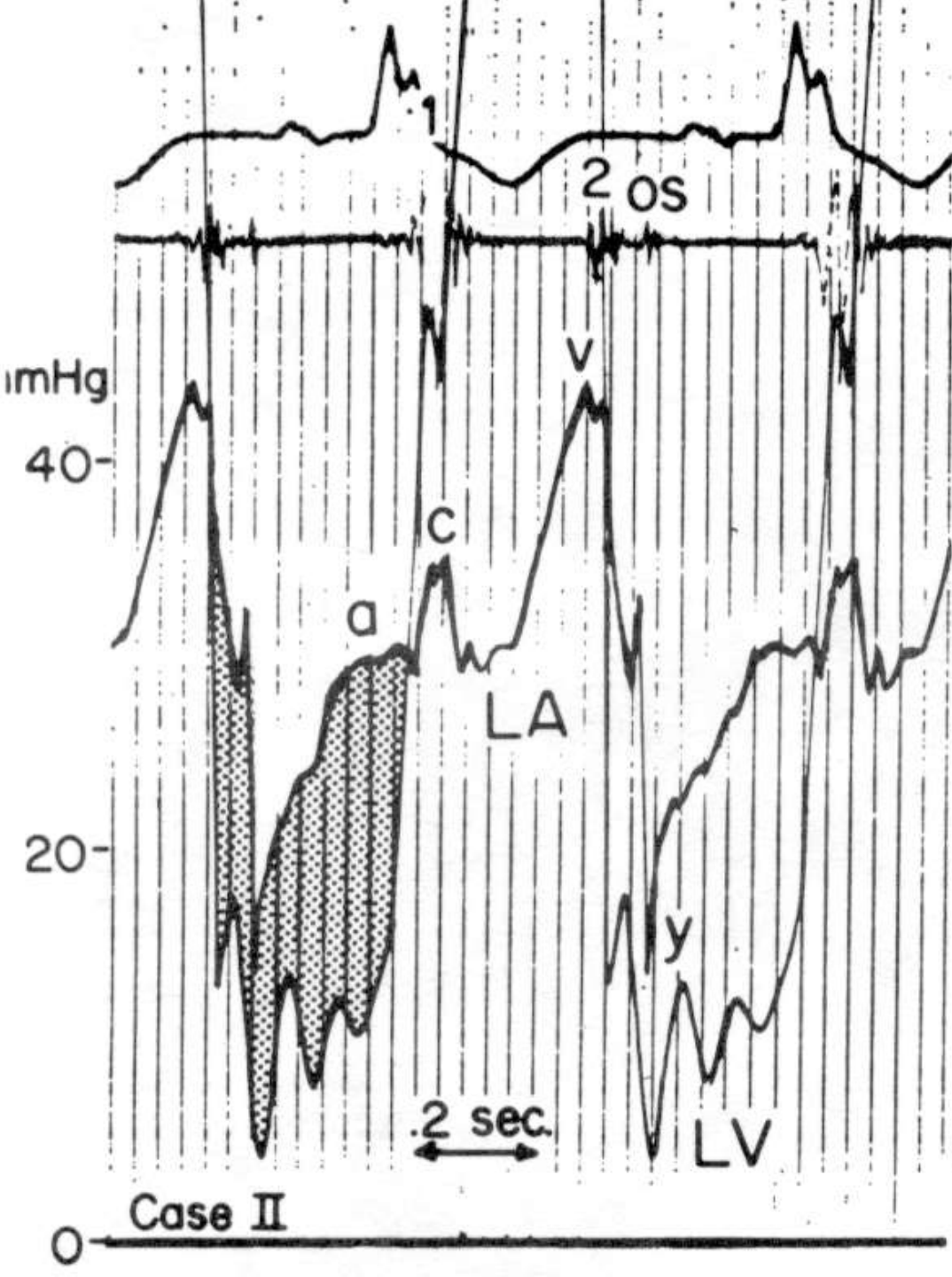
Criley JM and Ross RS, Tampa Tracings, 1971

Diagram of Events in LA Myxoma



Criley JM and Ross RS, Tampa Tracings, 1971

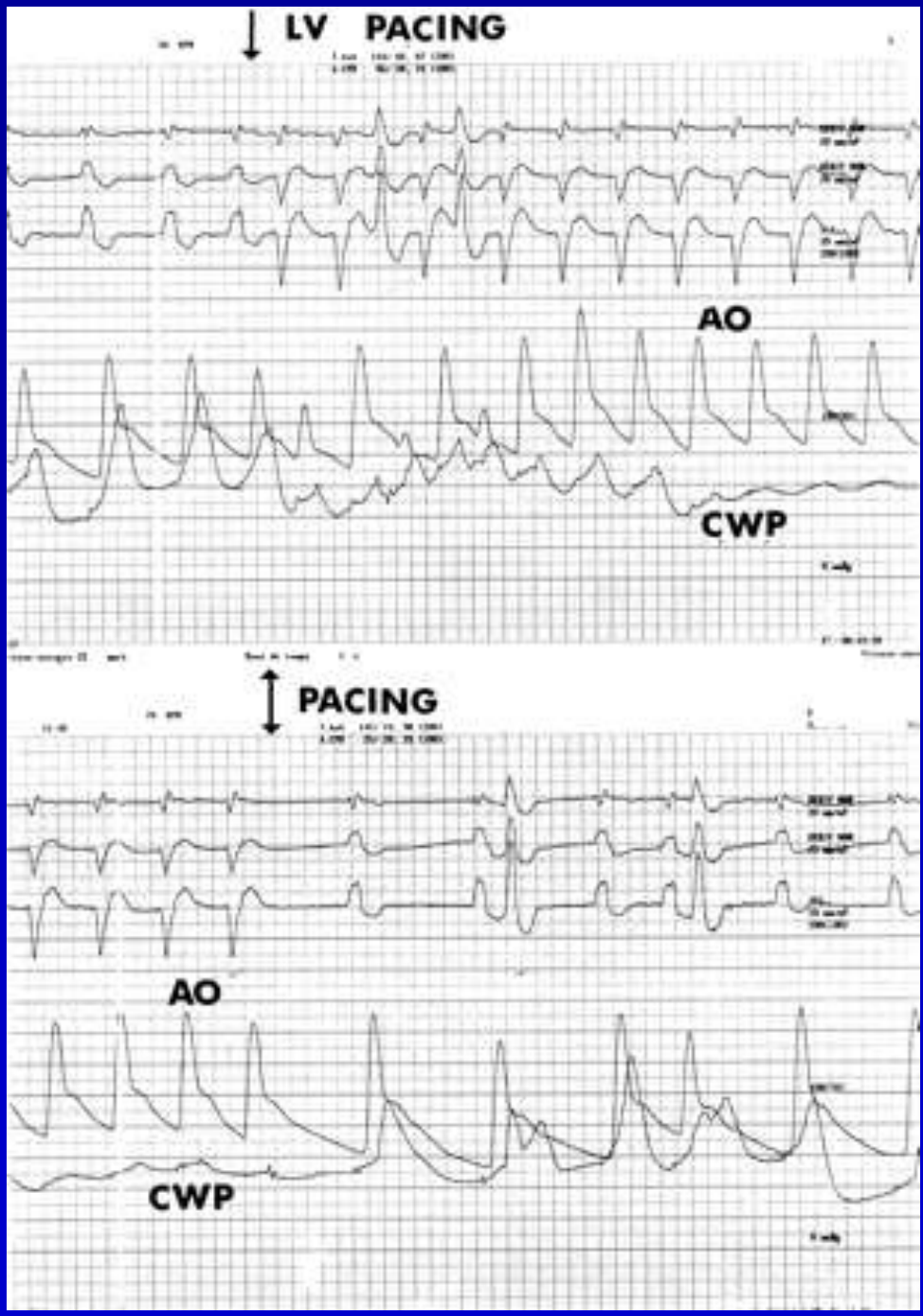
Obstruction in LA Myxoma



Criley JM and Ross RS. Tampa Tracings, 1971

Atrial fibrillation

Note decrease in pulmonary capillary wedge V wave when LV pacing is instituted

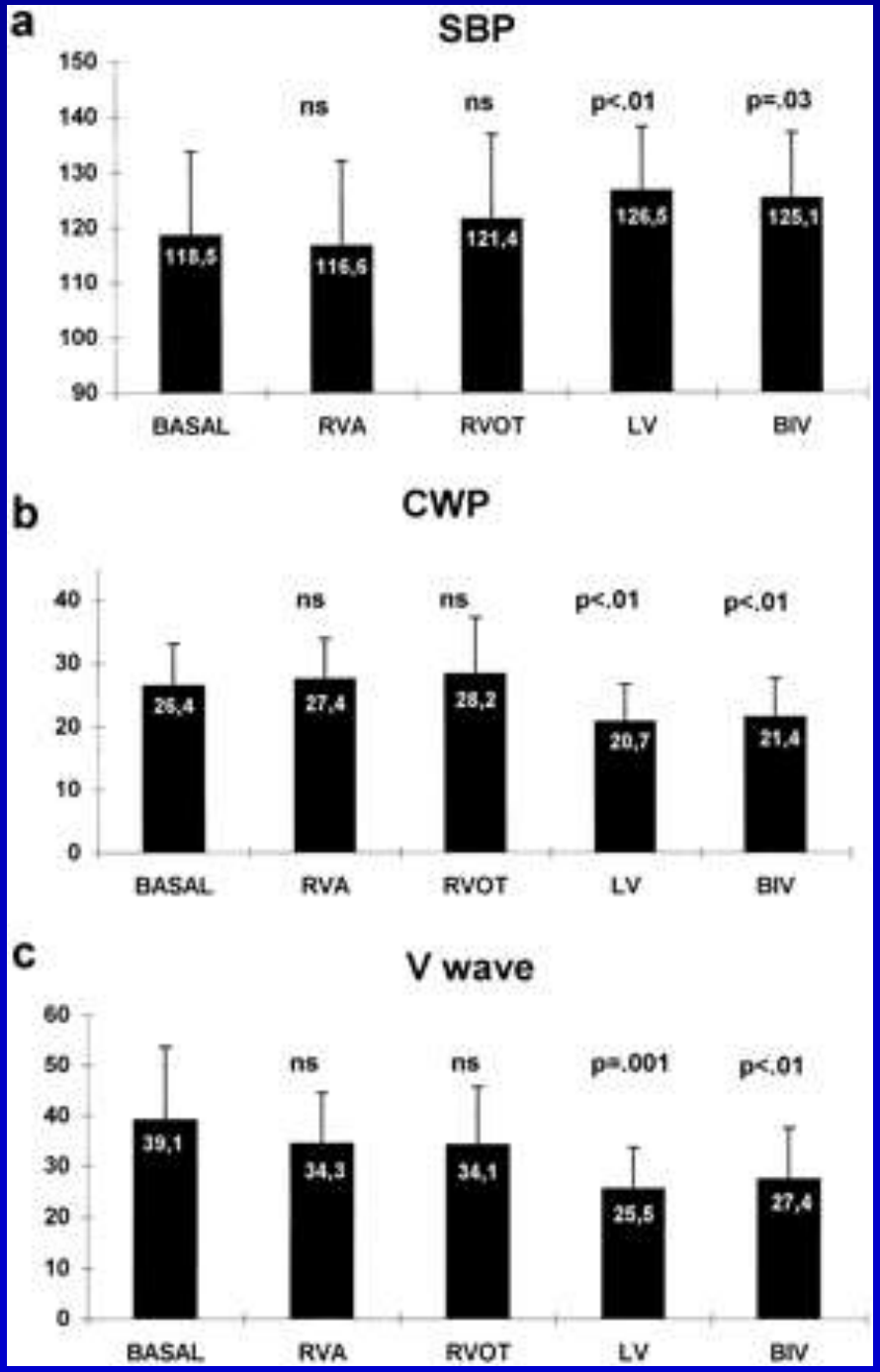


Blanc JJ et al. Circulation 1997;96:3273

Hemodynamic effects of different pacing sites in patients with severe CHF:

Effect on systolic BP, pulmonary capillary wedge pressure and pulmonary capillary wedge V wave

Large V wave often defined as > 10 mmHg + mean wedge



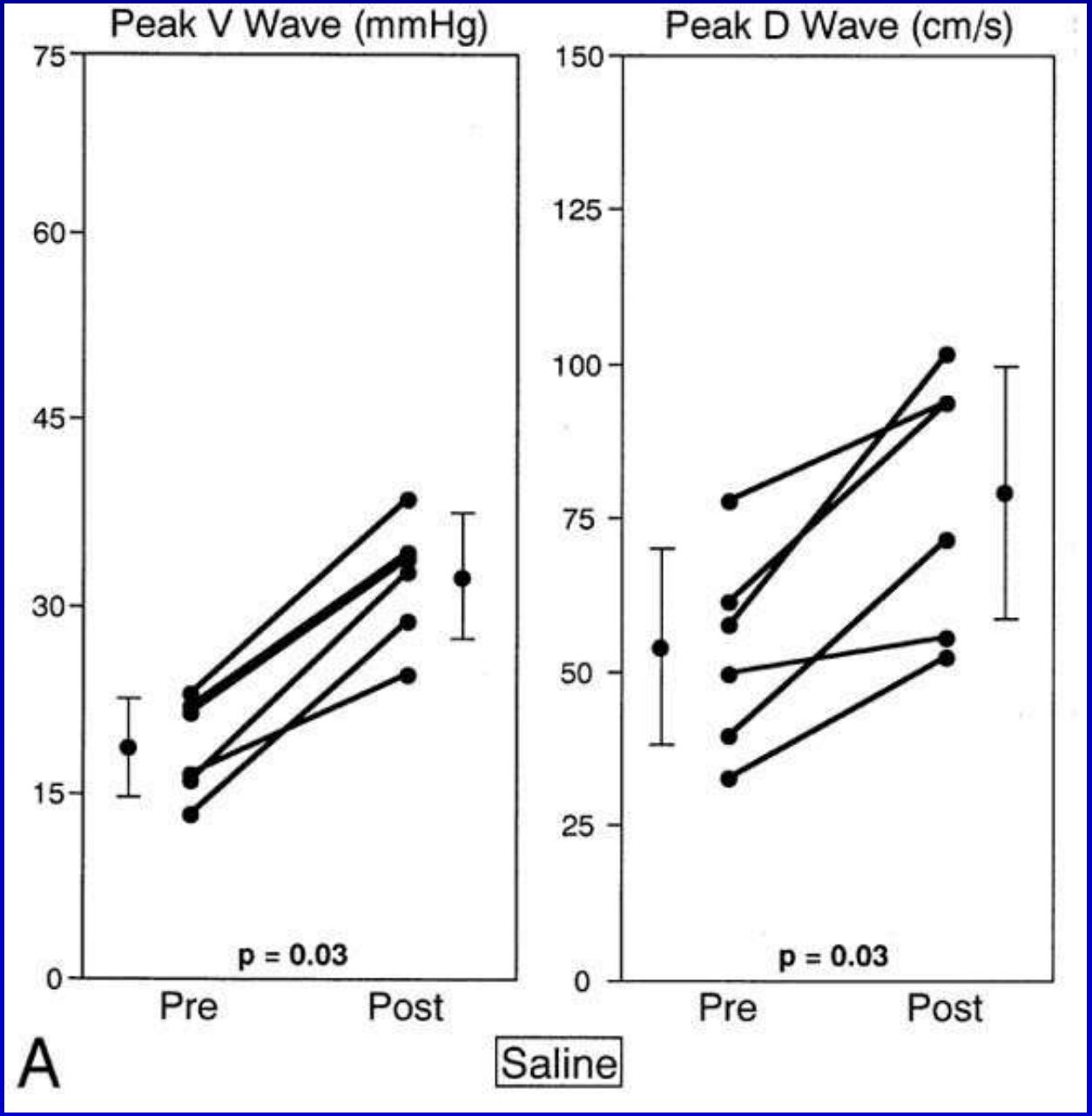
Blanc JJ et al. Circulation 1997;96:3273

Assessing the V wave in MR

- 25 patients studied with 3+ or 4+ MR, average age 52, most with MVP or flail, and control group of 5 patients with 1-2+ MR pre CABG, average age 70
- Study was intraoperative, pericardium open, direct LA cannulation, 24 inch tubing and resonance overshoot eliminator
- TEE 2 cm from orifice of LUPV (10%) or RUPV
- 4 Alterations in state to create 25% change in MAP or mean LA pressure
  - Saline infusion (6), 500-1000ml
  - Nitroglycerine (6), 0.6-2.6 mcg/kg/min
  - Phenylephrine (6), 0.1-2.6 mcg/kg/min (also control group)
  - Nitroprusside (7), 0.1-2.6 mcg/kg/min

Klein AL et al. J Am Soc Echocardiogr. 1997;10:41.

TEE in patients with MR, looking at correlation of V wave and LA pressure with PV Doppler patterns



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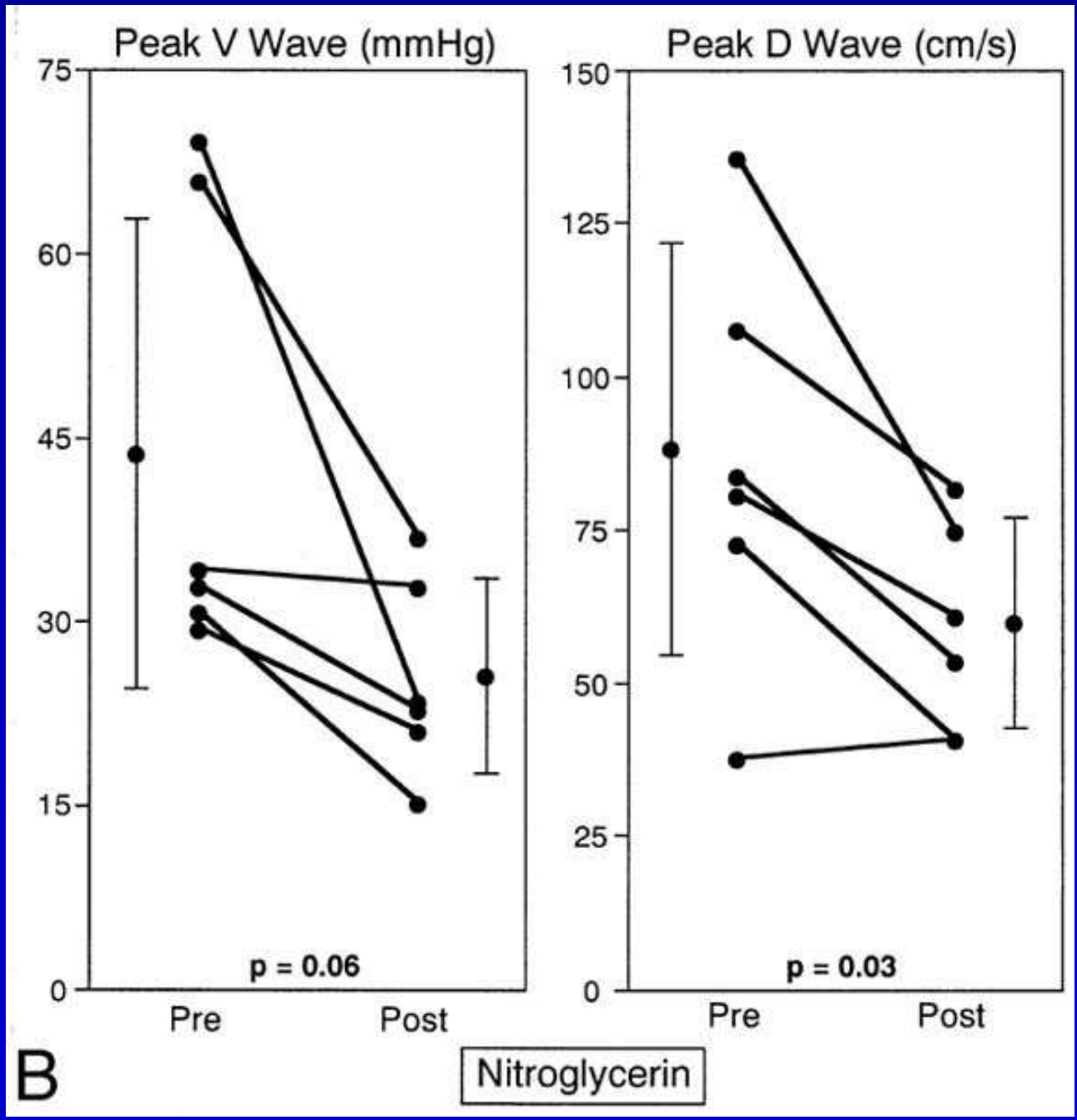
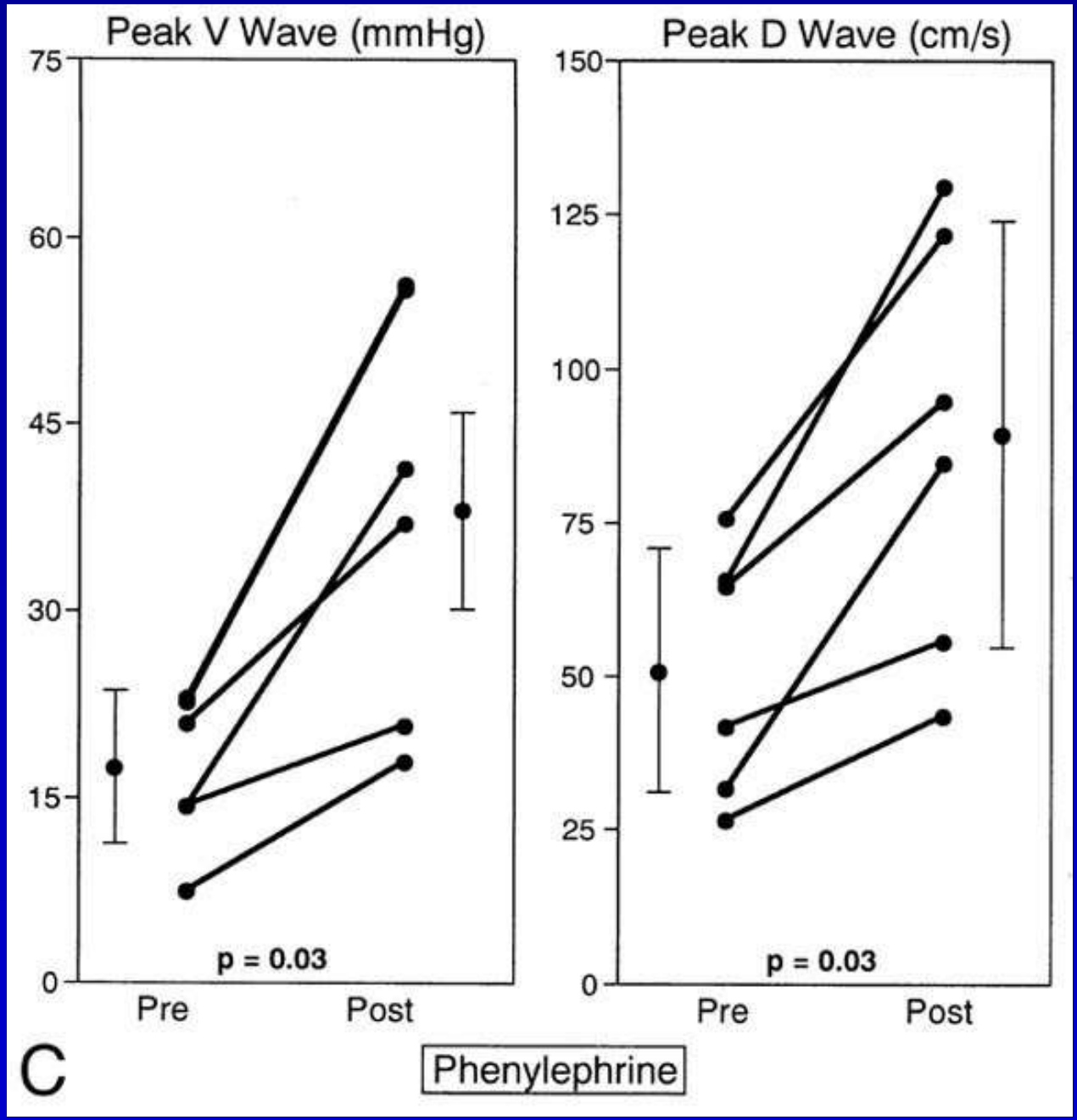
TEE in patients with MR, looking at correlation of V wave and LA pressure with PV Doppler patterns



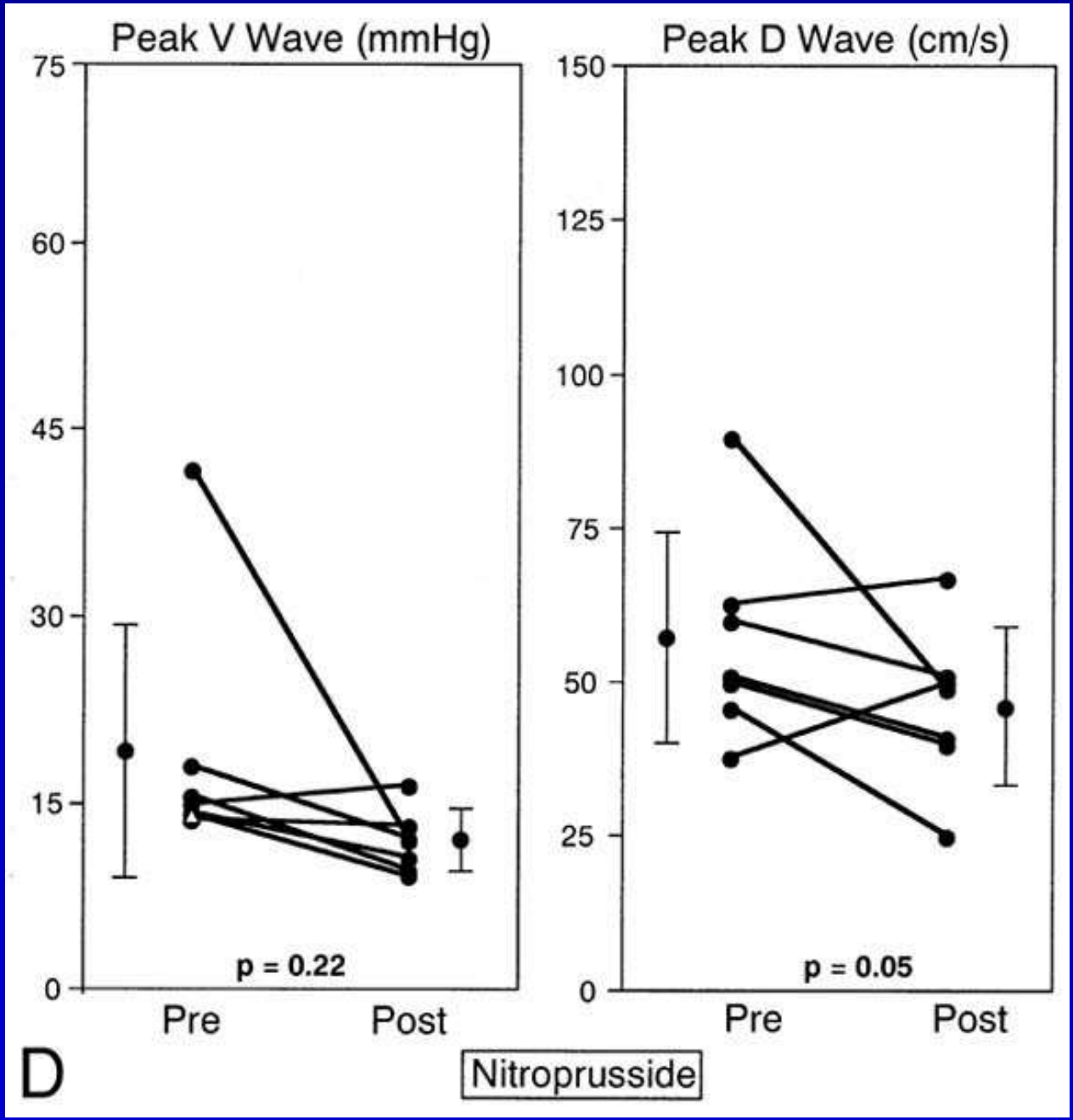
Klein AL et al. J Am Soc Echocardiogr. 1997;10:41.

TEE in patients with MR, looking at correlation of V wave and LA pressure with PV Doppler patterns



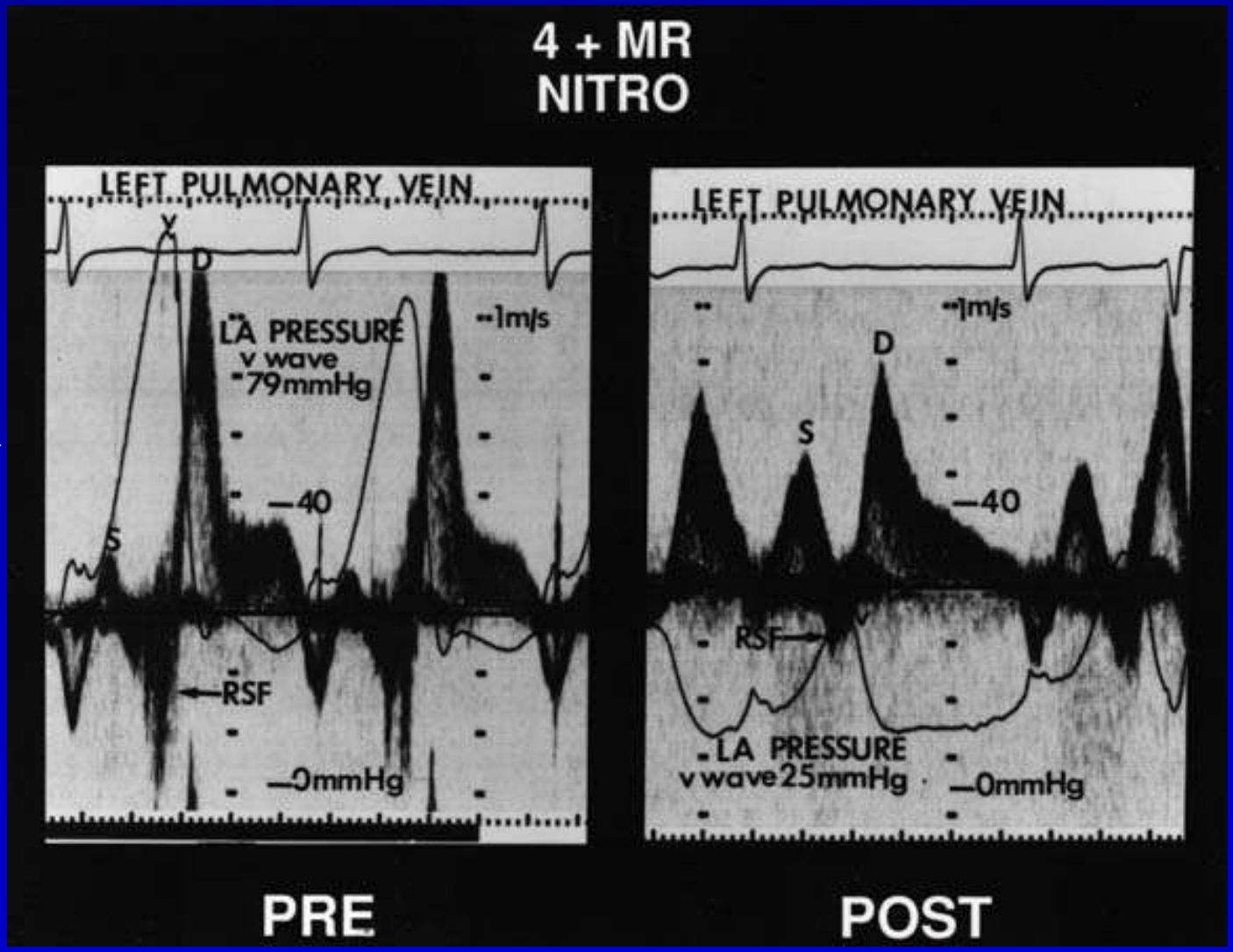
Klein AL et al. J Am Soc Echocardiogr. 1997;10:41.

TEE in patients with MR, looking at correlation of V wave and LA pressure with PV Doppler patterns



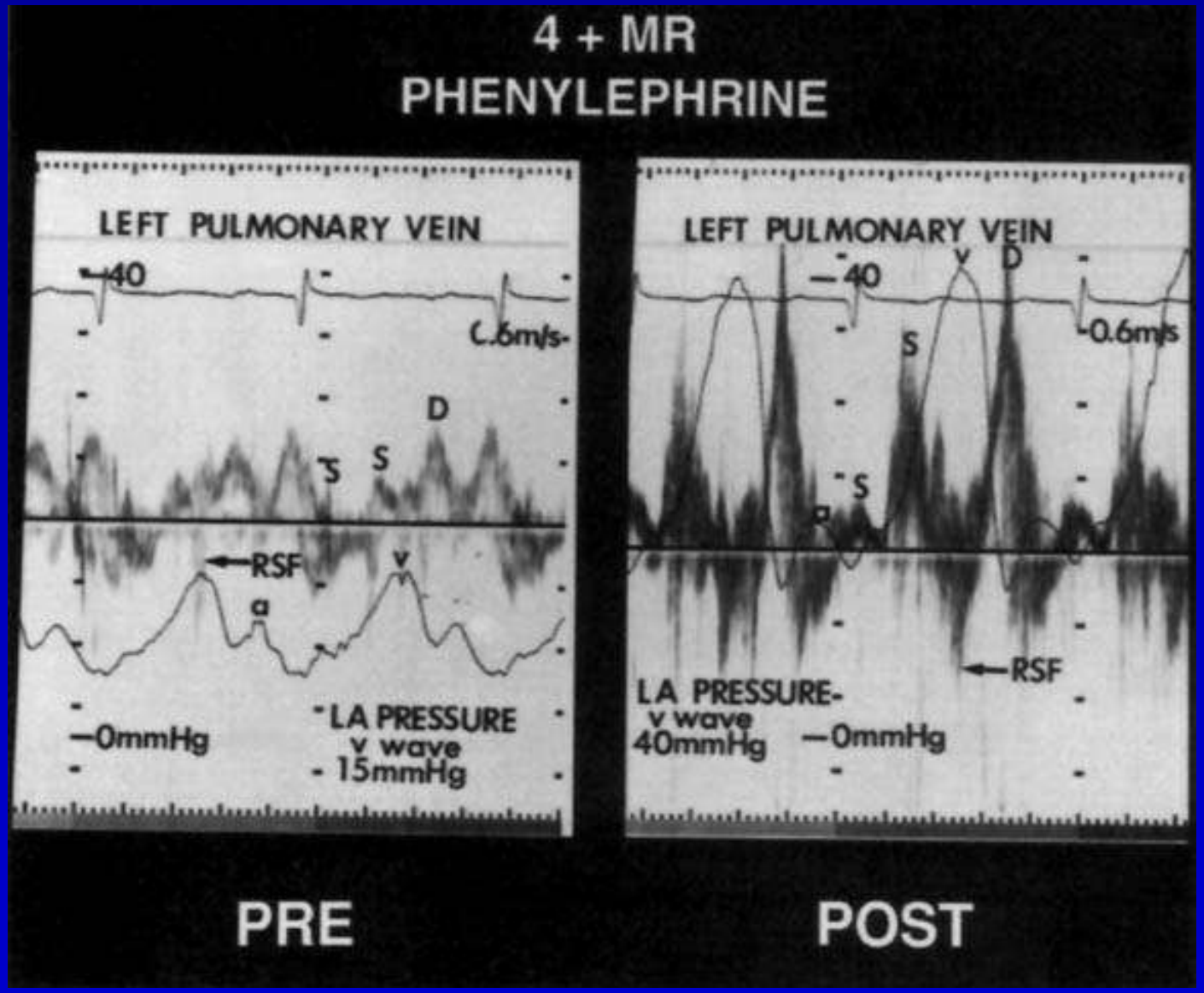
Klein AL et al. J Am Soc Echocardiogr. 1997;10:41.

TEE in patients with MR, looking at correlation of V wave and LA pressure with PV Doppler patterns

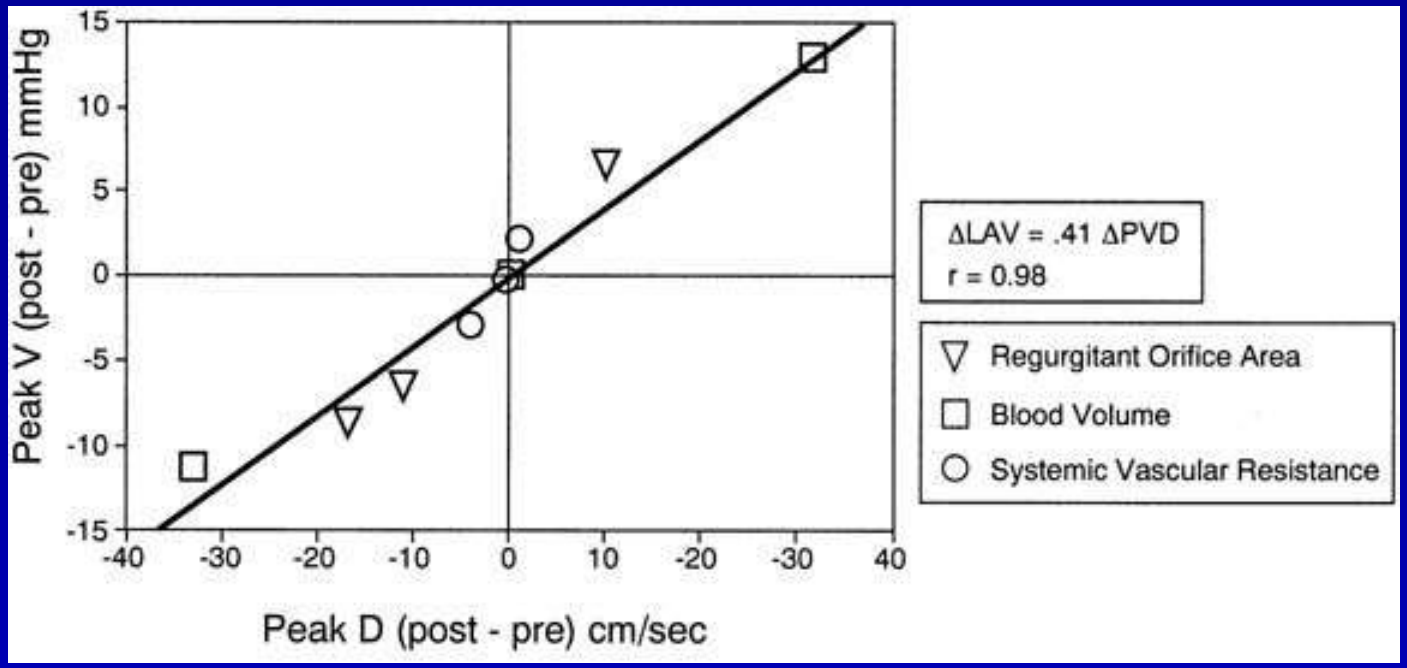


Klein AL et al. J Am Soc Echocardiogr. 1997;10:41.

TEE in patients with MR, looking at correlation of V wave and LA pressure with PV Doppler patterns



Klein AL et al. J Am Soc Echocardiogr. 1997;10:41.



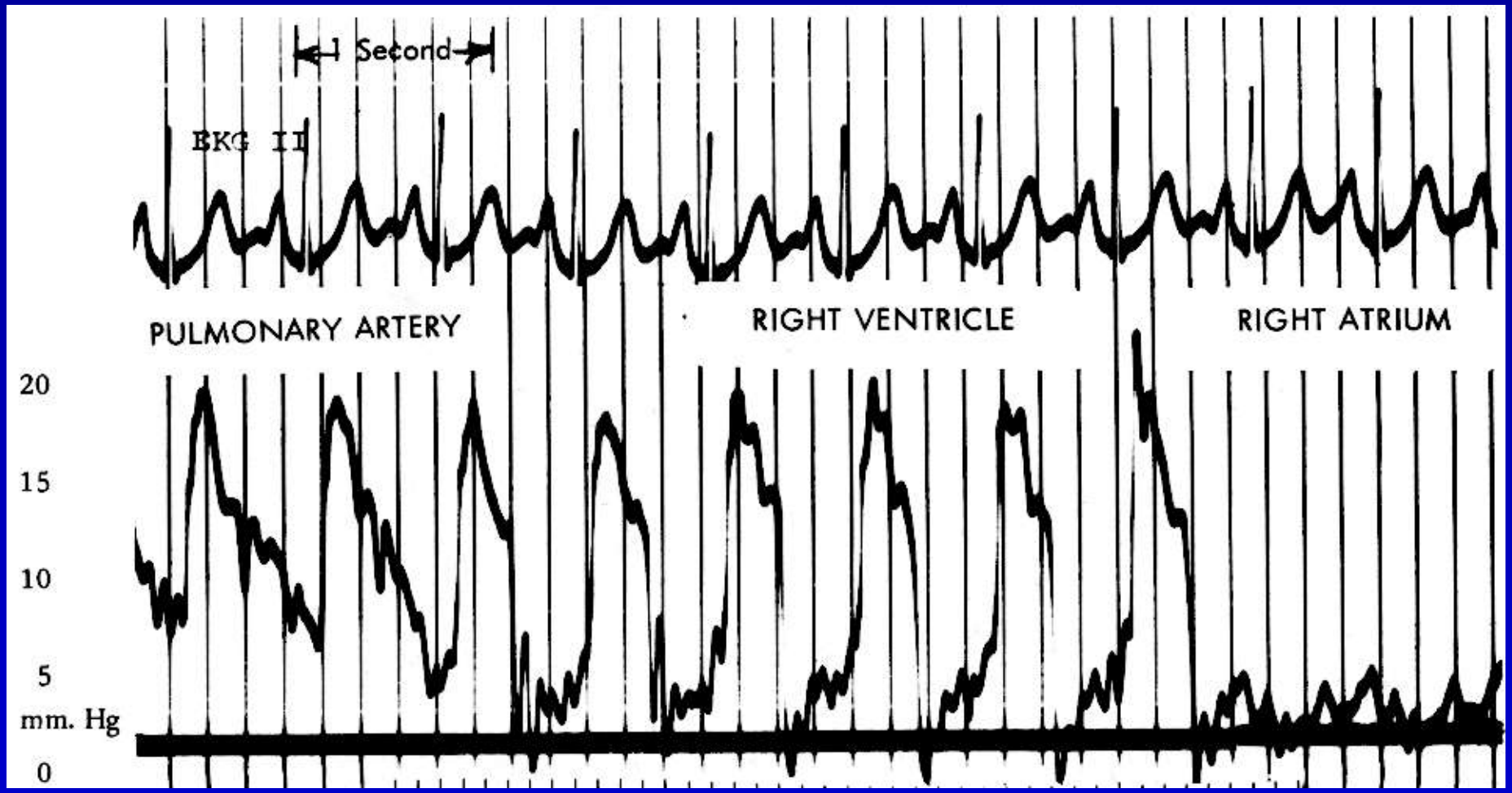
Numeric plots of change in V and D with different alterations of state, with systemic vascular resistence showing steeper slope, that is more of a change in V wave considering the change in D wave

Klein AL et al. J Am Soc Echocardiogr. 1997;10:41.

Tricuspid Valve V Wave

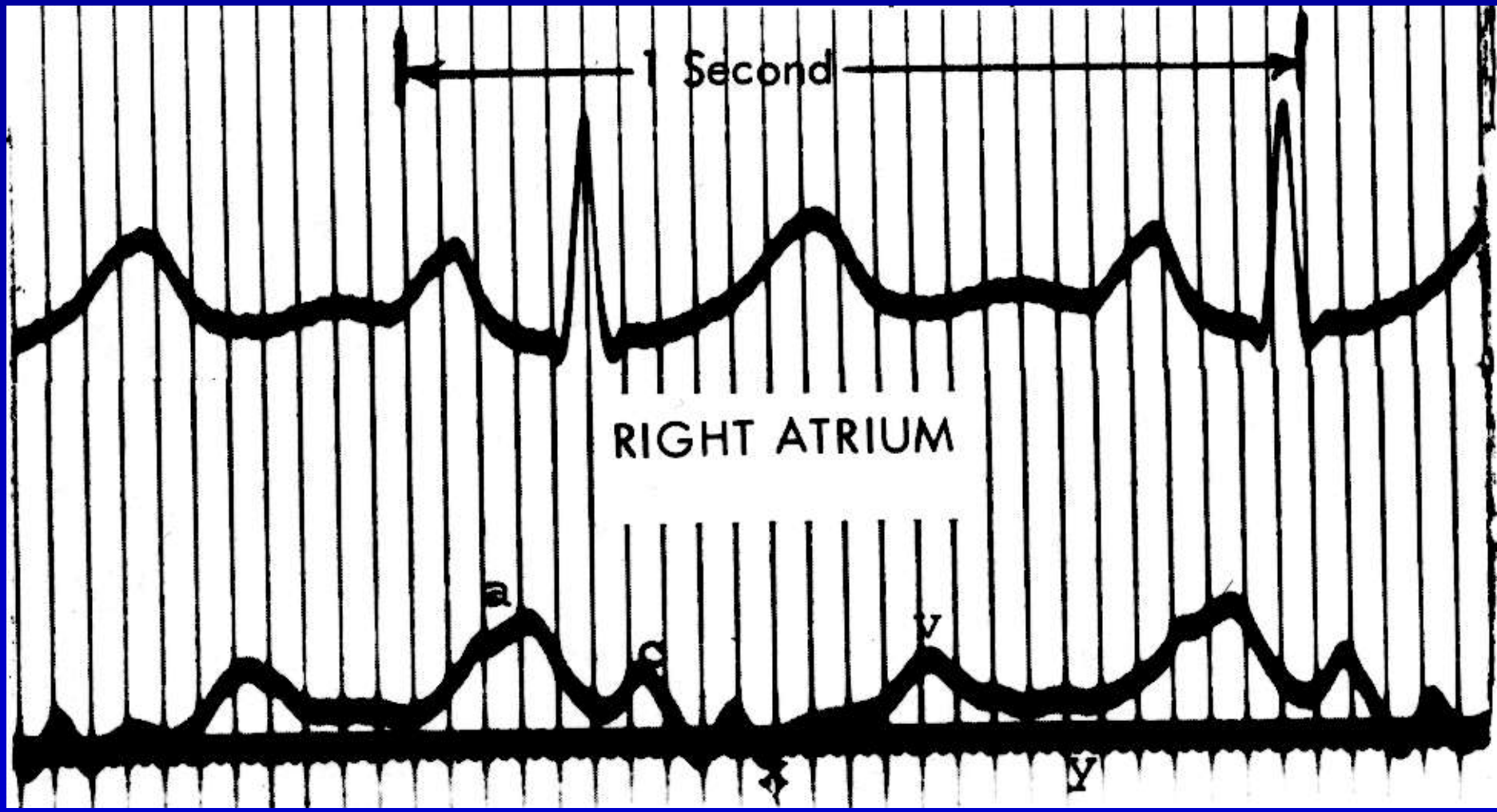
- Normally in the RA, the A wave dominates, whereas in the LA, the V wave dominates
- Causes of large TV V waves:
  - TR almost exclusively
  - Similar to LA, volume load into an already loaded RA
- Fine point important to some: A systolic wave from regurgitation may not be called a V wave, but a systolic regurgitant wave.

Normal Right Heart Waveforms



Criley JM and Ross RS, Tampa Tracings, 1971

Normal RA Pressure Waveform

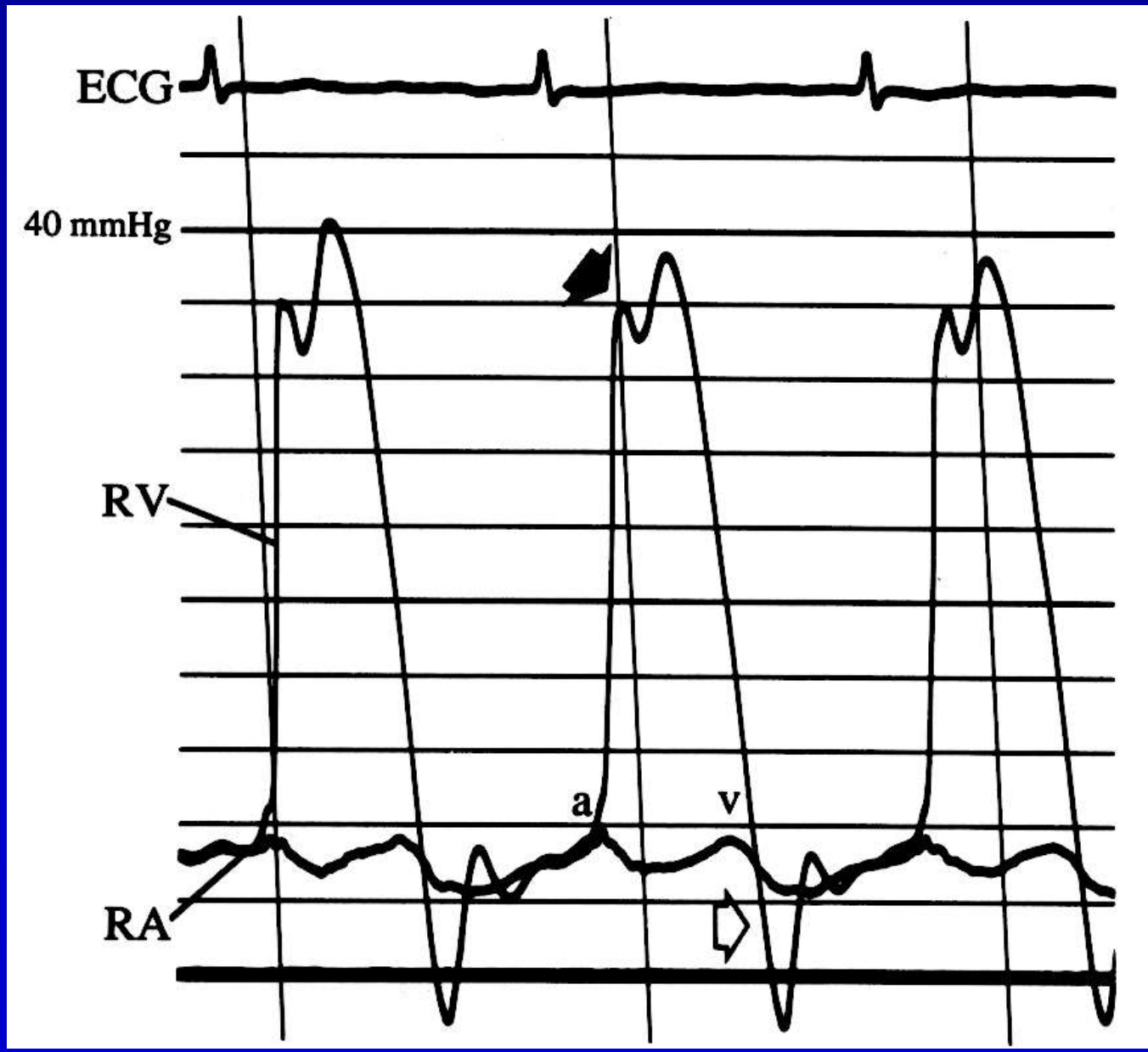


Criley JM and Ross RS, Tampa Tracings, 1971

Normal RA and RV Pressure Relationship

Notes:

RV pressure
not normal
(COPD).
RV waveform
underdamped.
RA c wave
inapparent.
a wave 7
v wave 7
mean 6
nadir Y descent 4



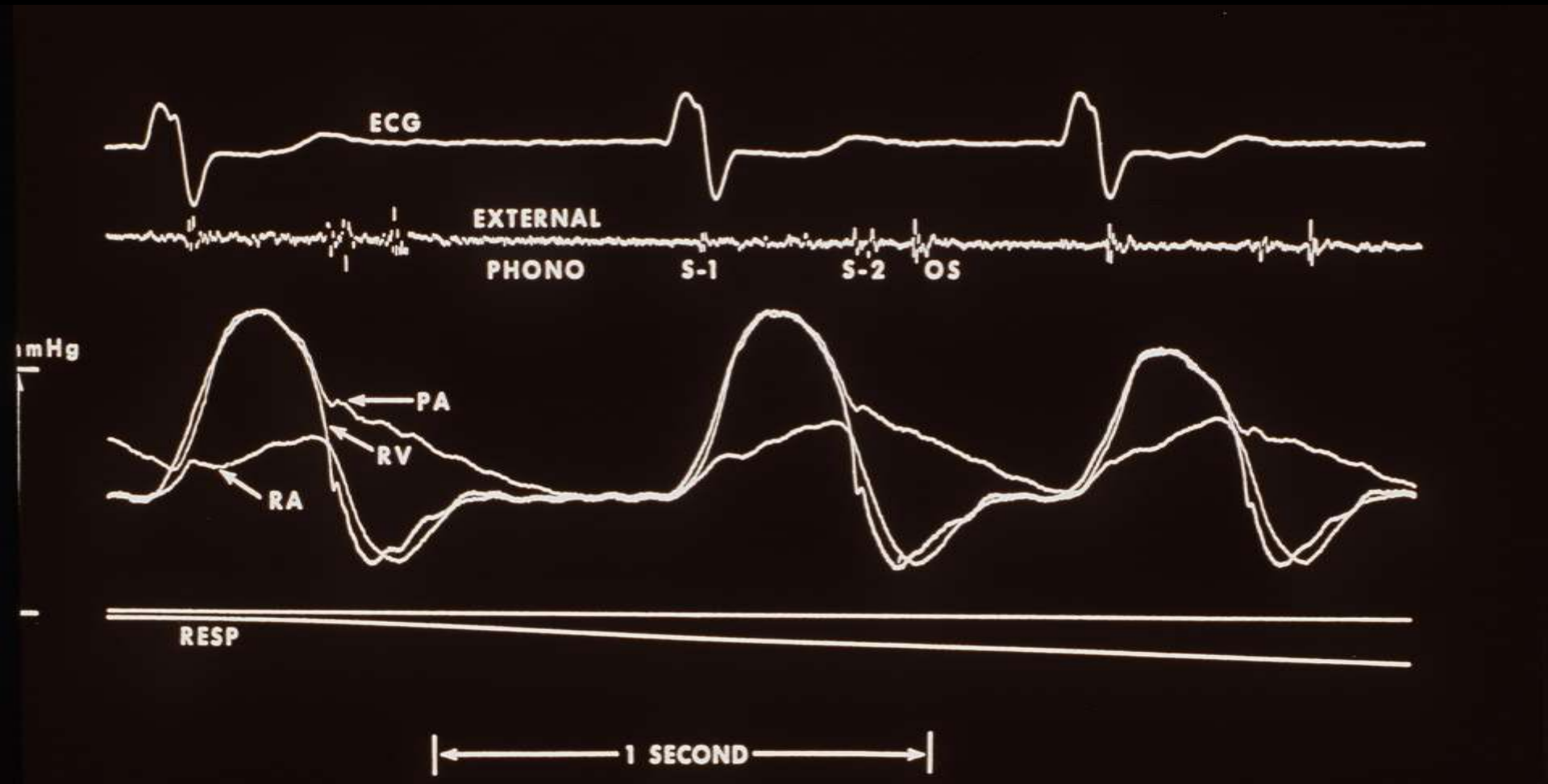
Kern, 1999, p. 102

RA and LA Relationship

62 yo man with aortic stenosis… LA is 22 (no MR), RA is 10

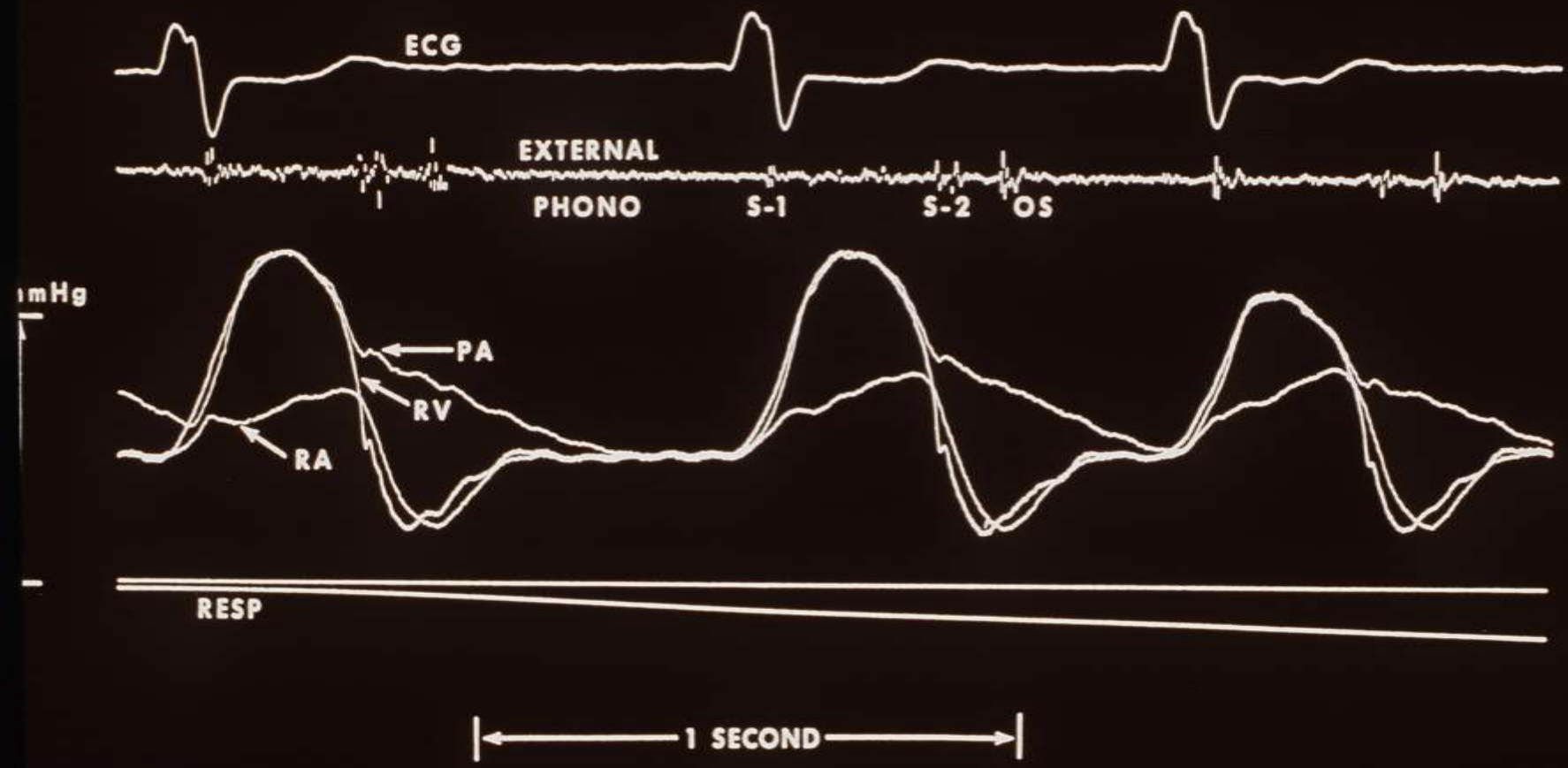
Kern, MJ, 1999, p. 103

Interpret the waveforms

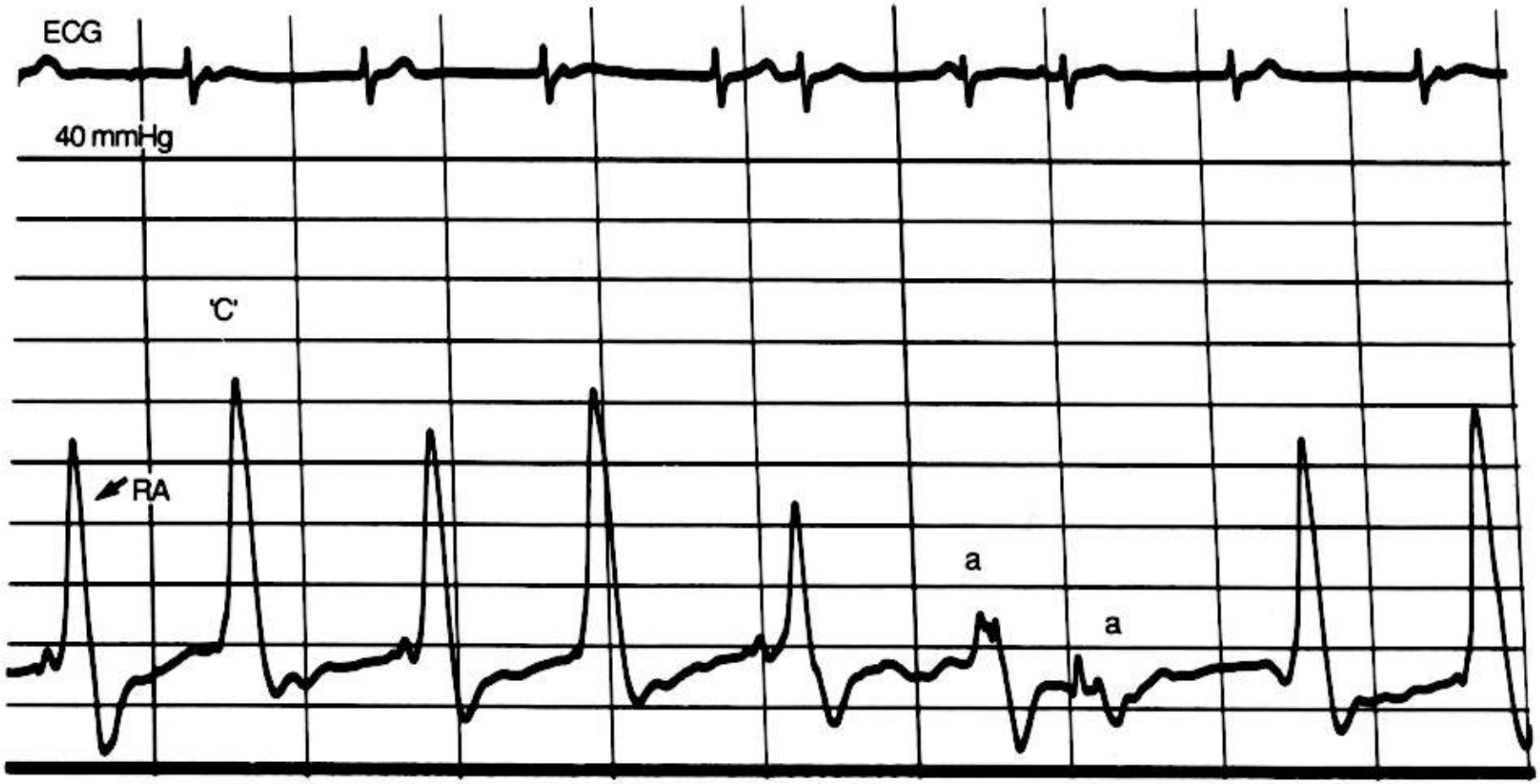


RHEUMATIC VALVULAR HEART DISEASE - TRICUSPID INSUFFICIENCY

(PROSTHETIC MITRAL VALVE)

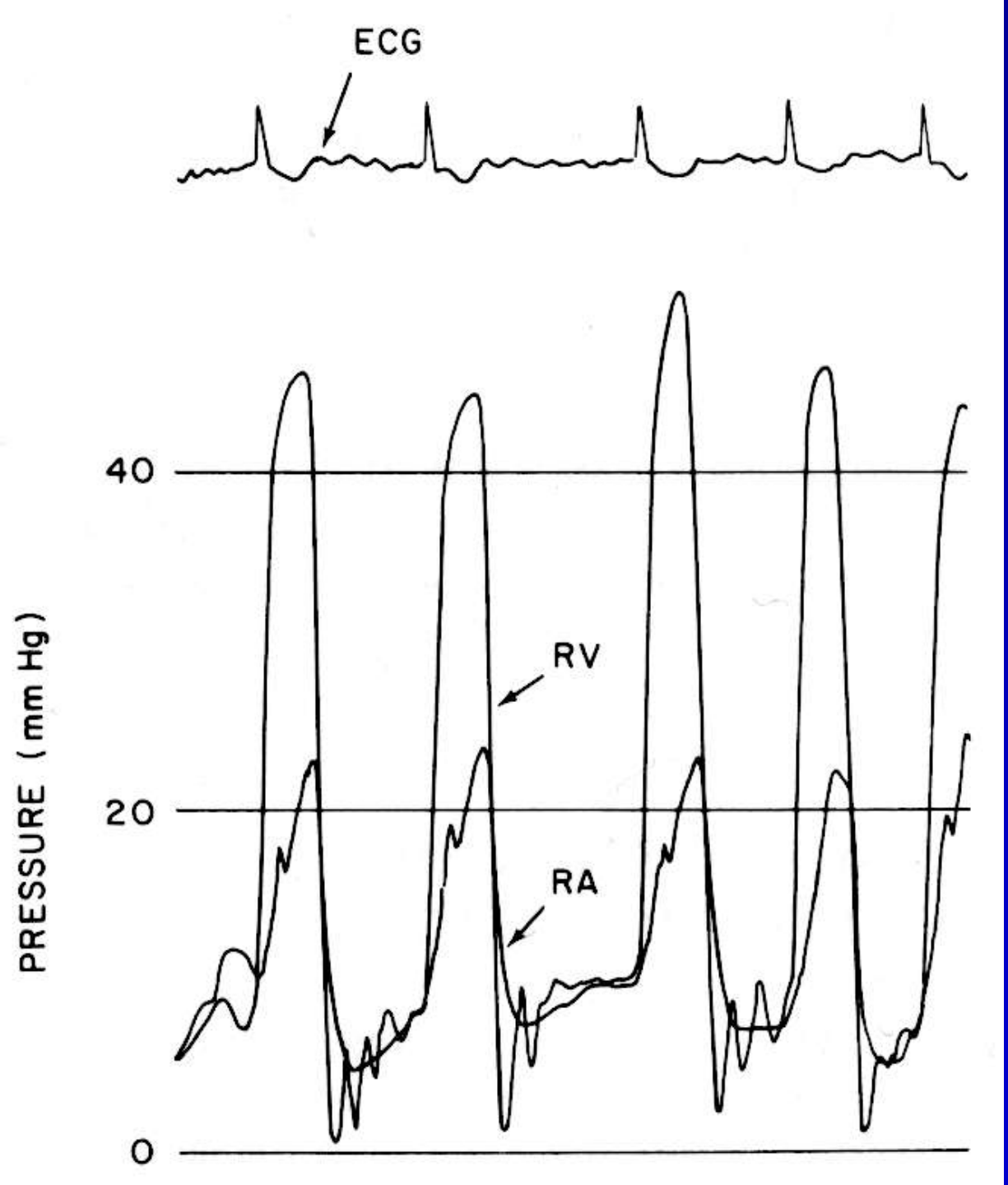


Dysrhythmia and RA pressure



Kern, MJ, 1999, p. 103

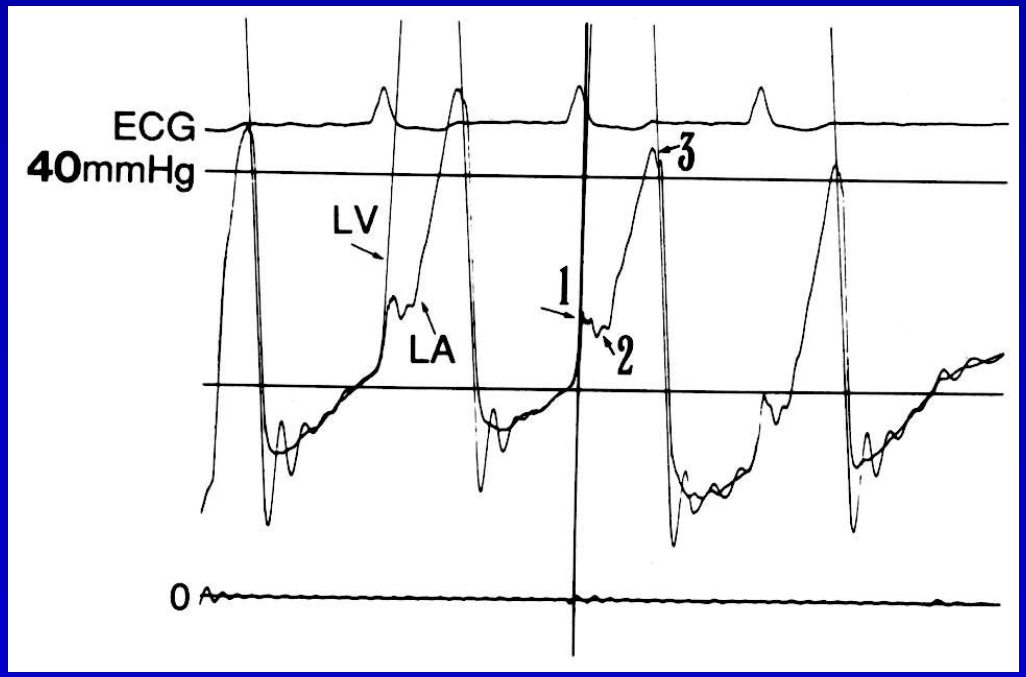
66 year-old man after MI

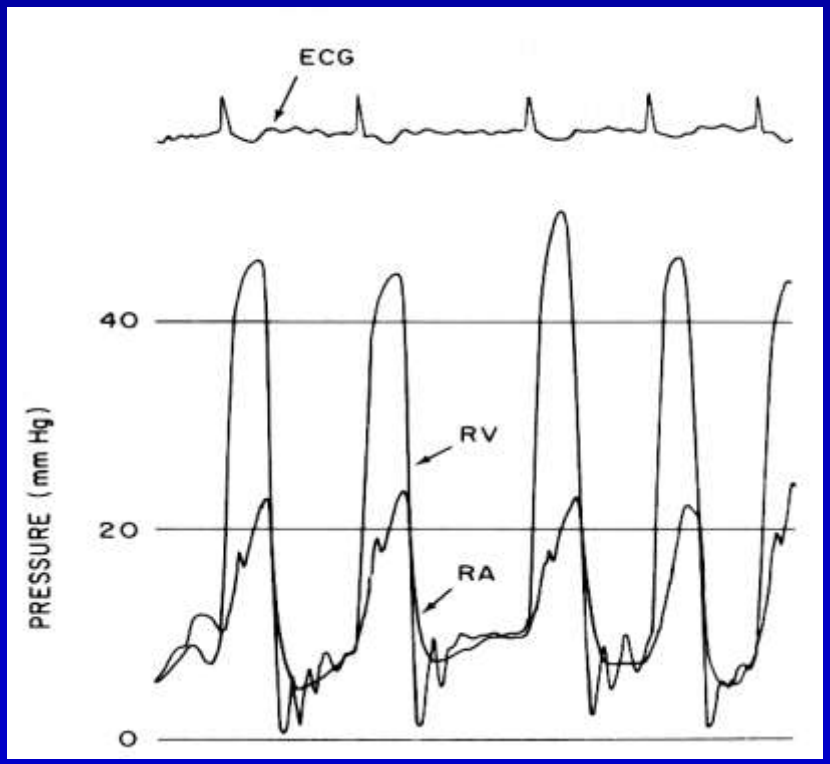


RA large V wave in TR and AF

Grossman, 2000, p. 780.

Comparison of RA and LA V waves





Kern, p. 98.

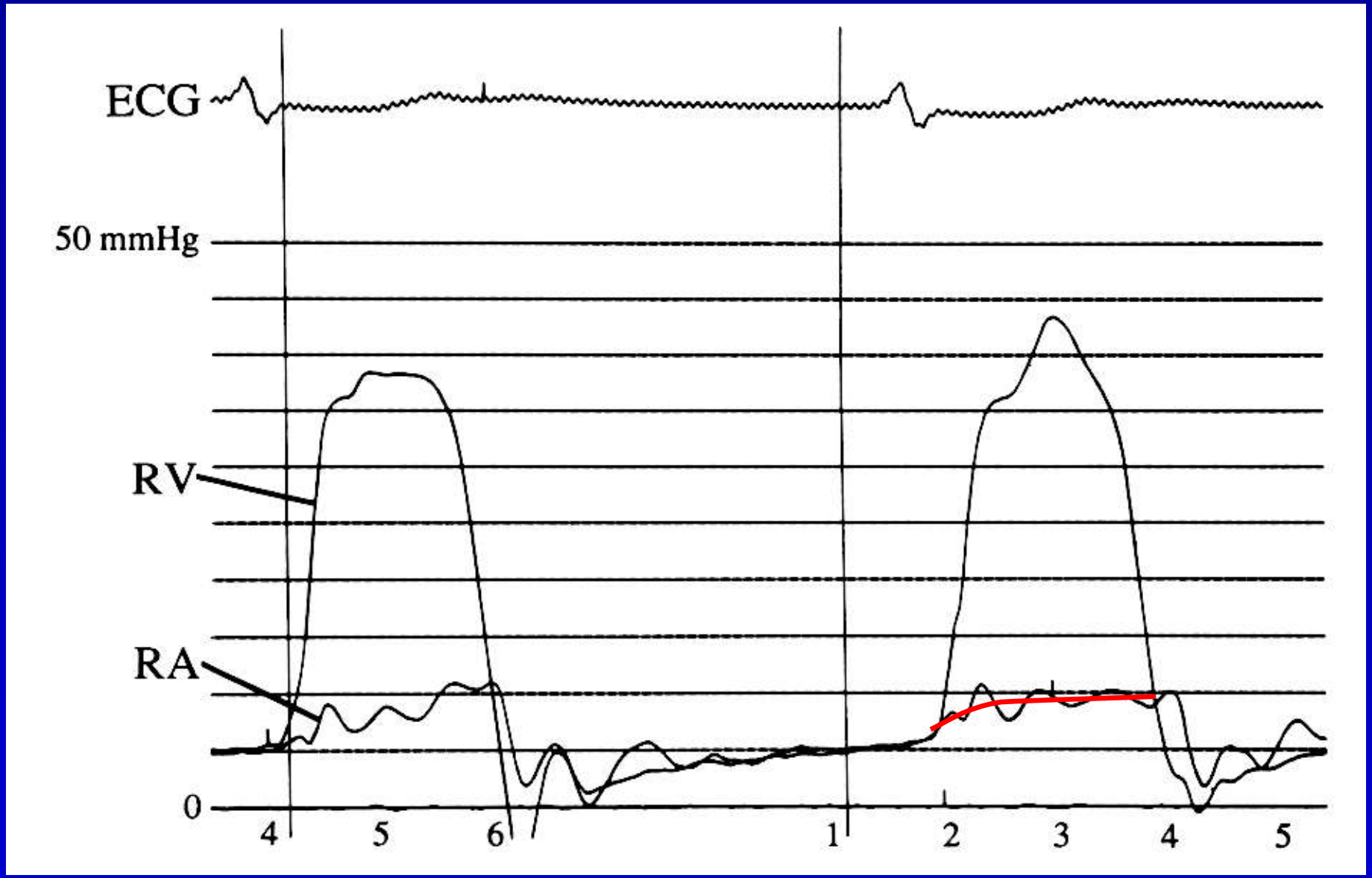
Grossman, 2000, p. 780

Effect of Rhythm on RA Pressure

Kern, p.104

Compensated CHF, unusually narrow “a” wave suggests artifact

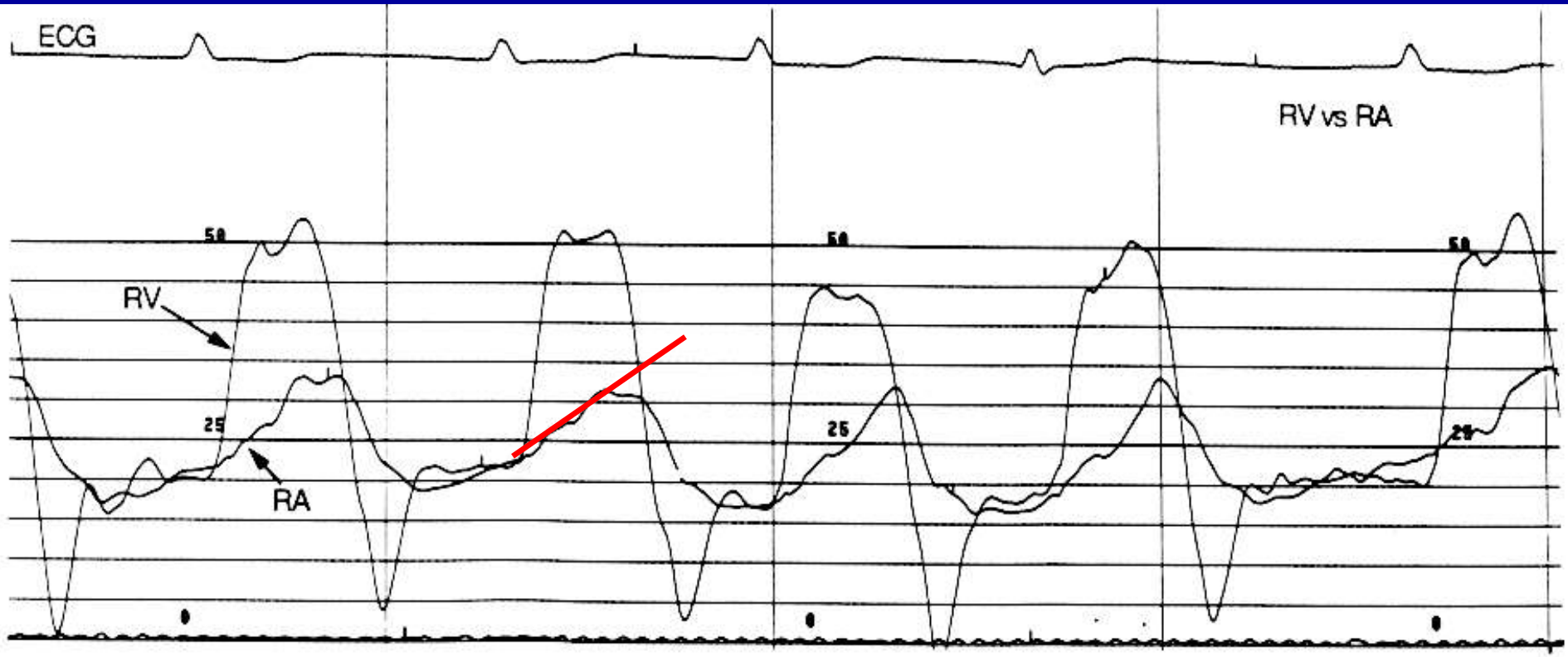
Rheumatic Fever History and Edema



50 year old woman. Rhythm? Note Y descent. TS?

Kern, p.104

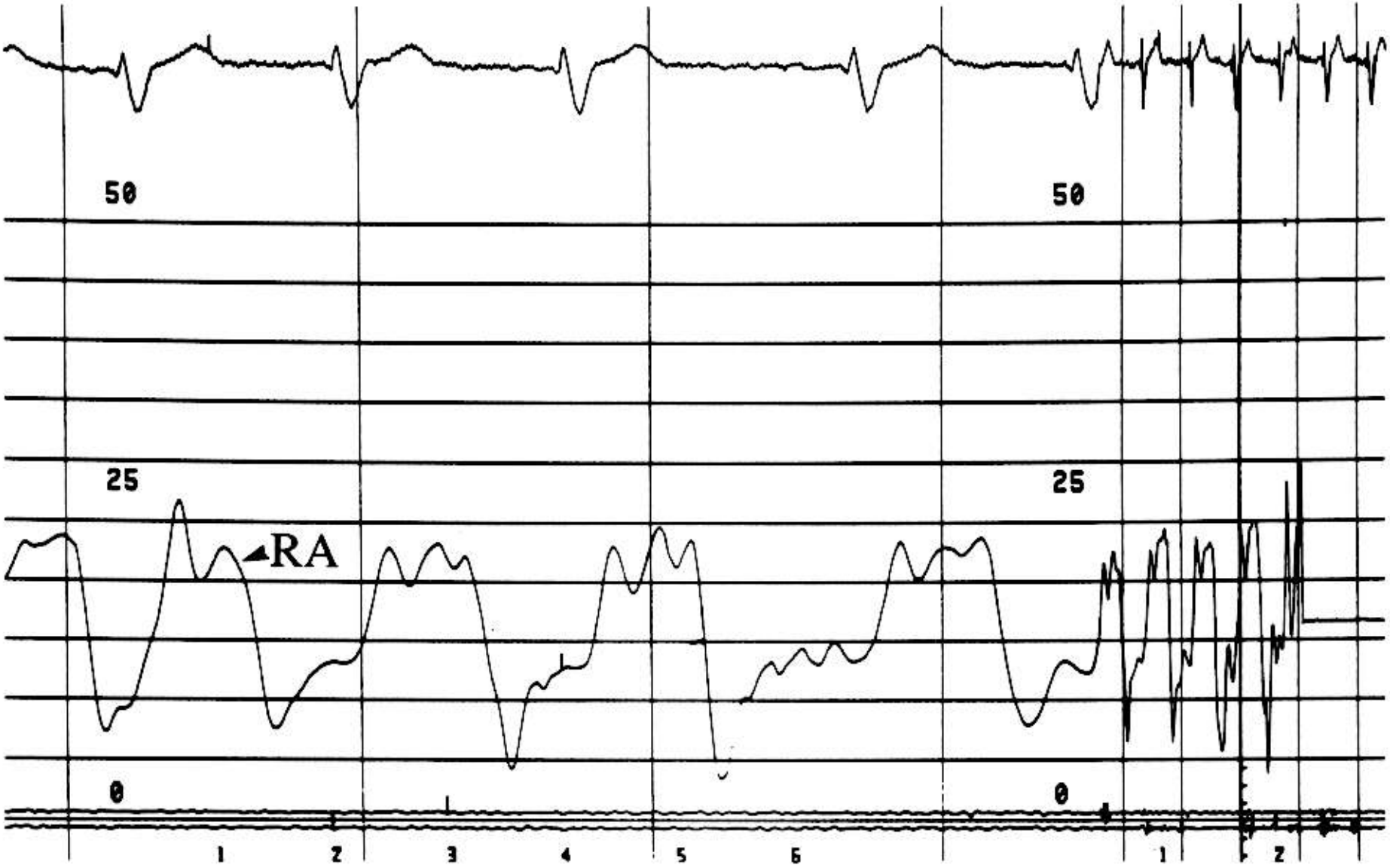
Severe Ascites and Dyspnea



39 year old woman. V wave 32 mmHg. Early RA-RV gradient equilibrates in the first 1/3 of diastole, torrential flow.
Rapid Y descent.

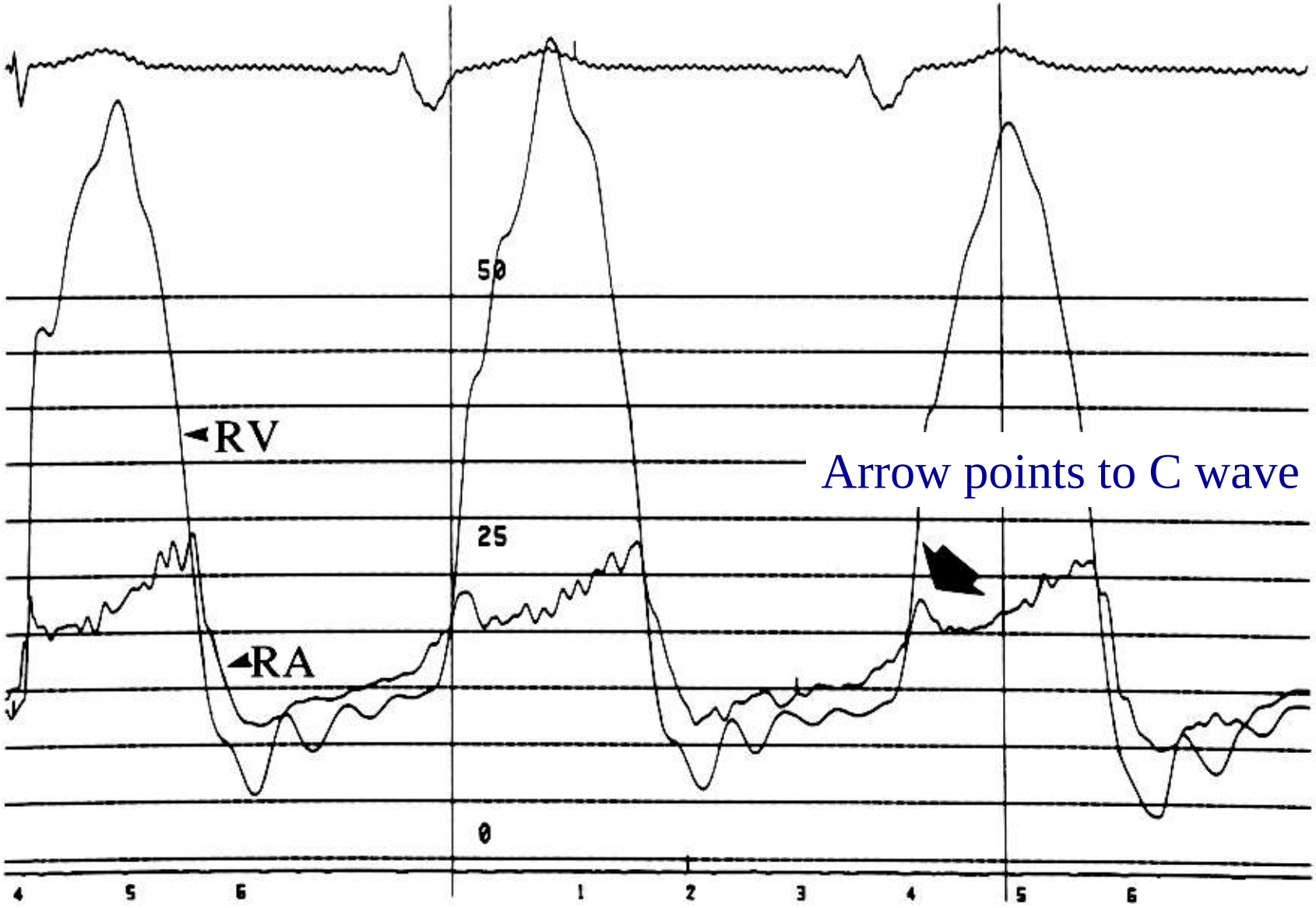
Kern, p.105

Increasing Abdominal Girth



Kern, p. 106 49 year old woman, systolic and diastolic murmurs

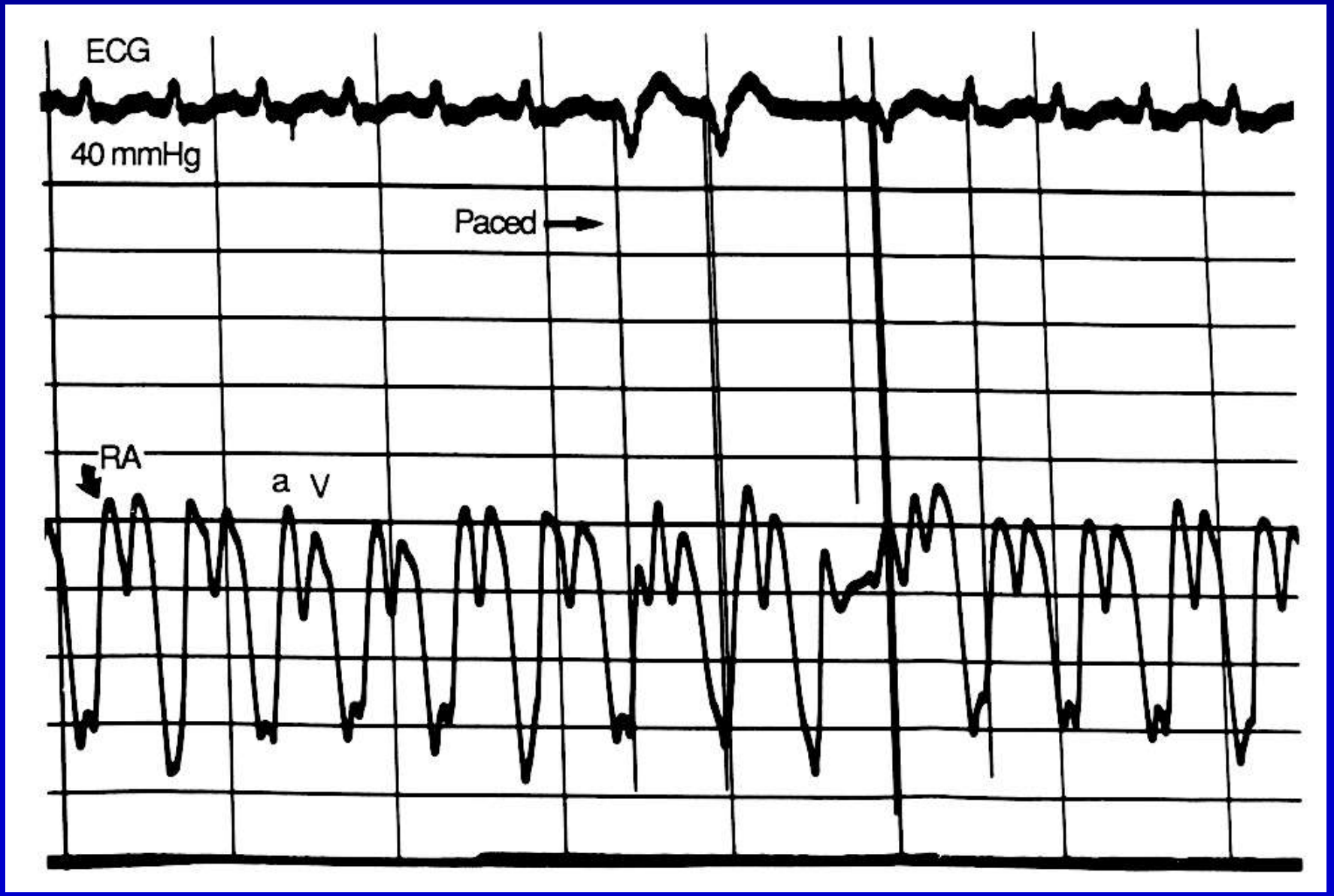
Systolic and Diastolic Murmurs



Arrow points to C wave

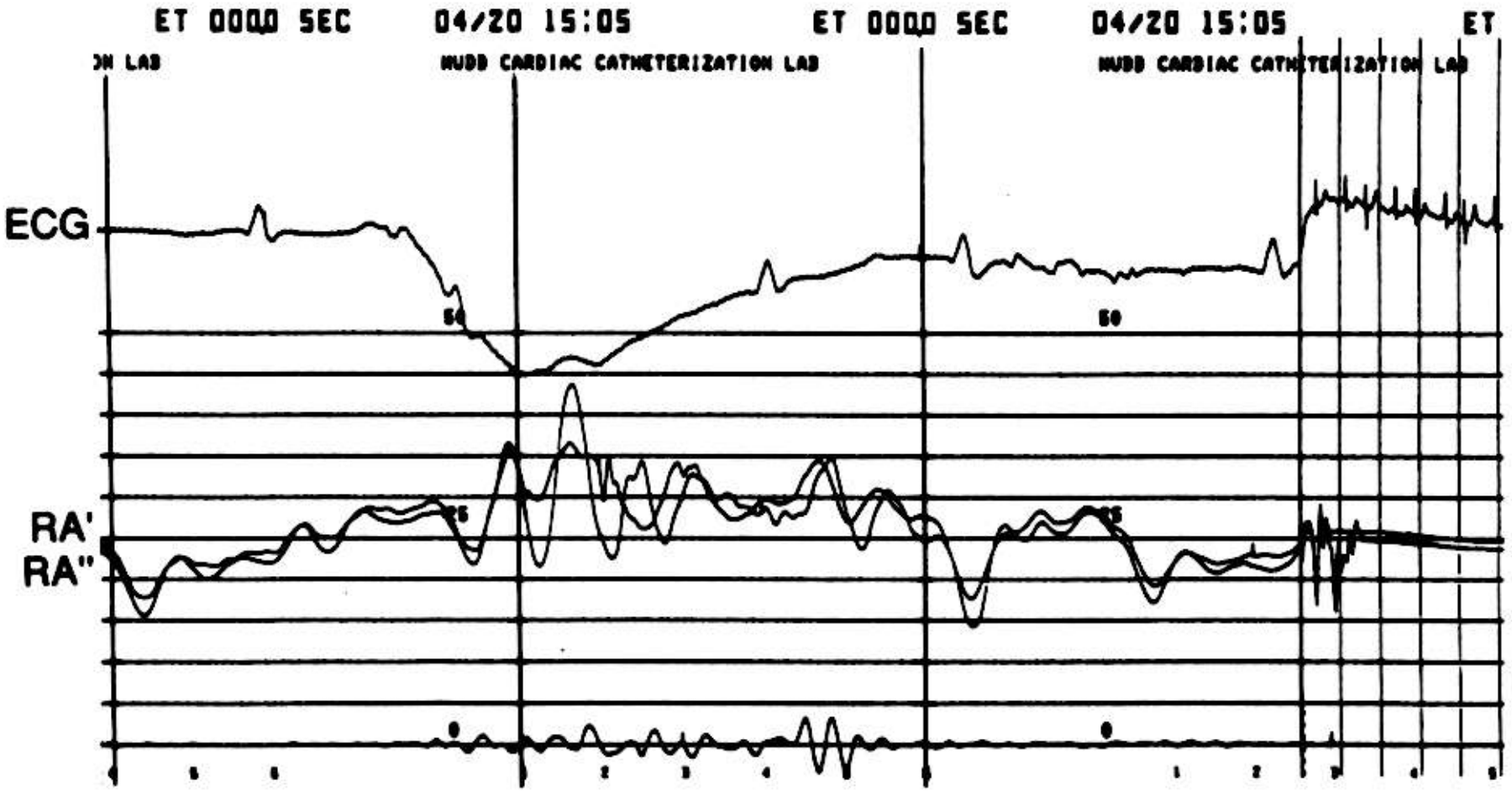
Kern, p. 106 49 year old woman, small diastolic gradient is significant

TR Can be Confused with CP



Kern, p. 107

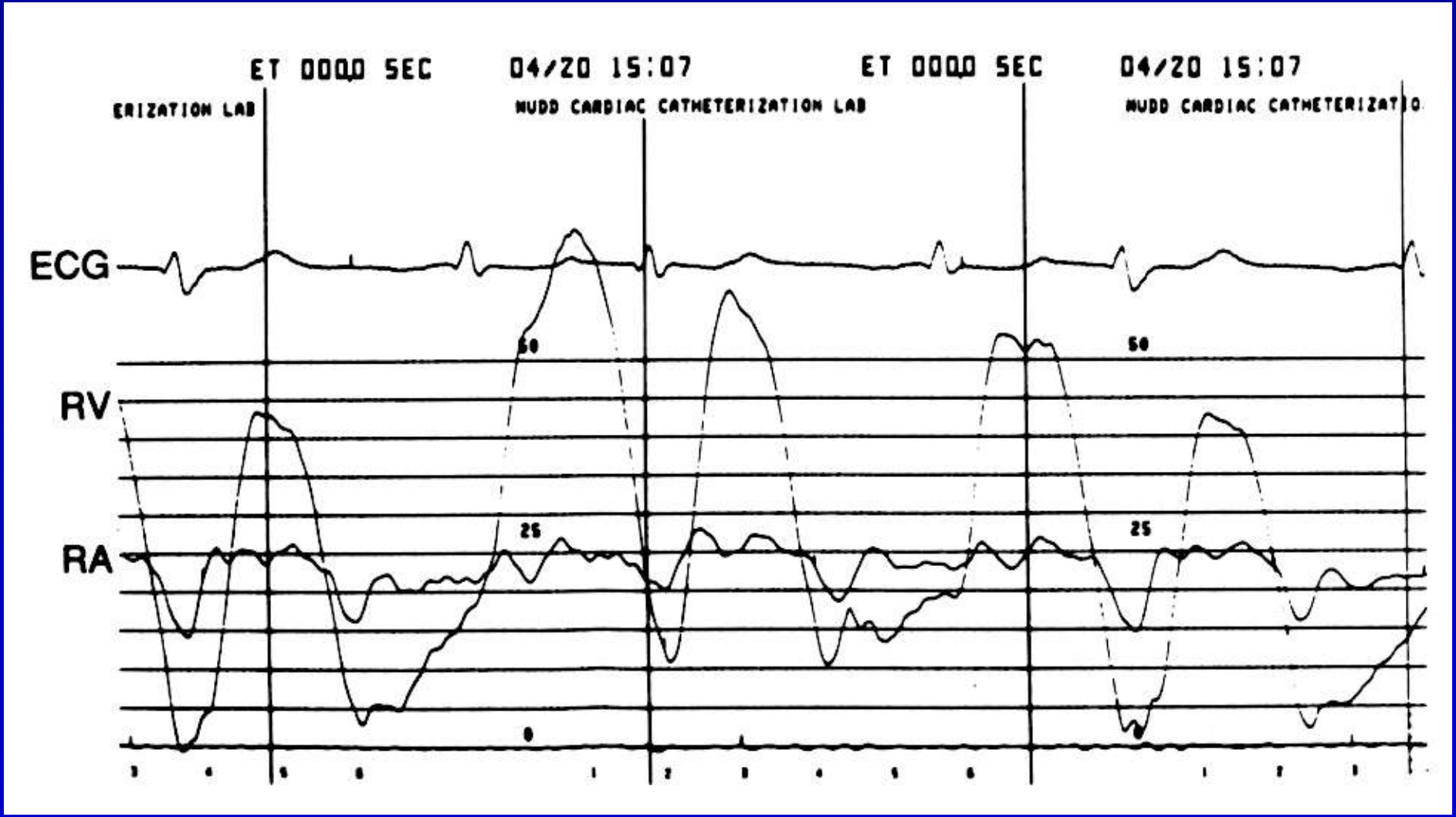
66 year old woman with edema



Prior tricuspid valve procedure, matched and elevated RA pressure, Atrial bigeminy.

Kern, p. 107

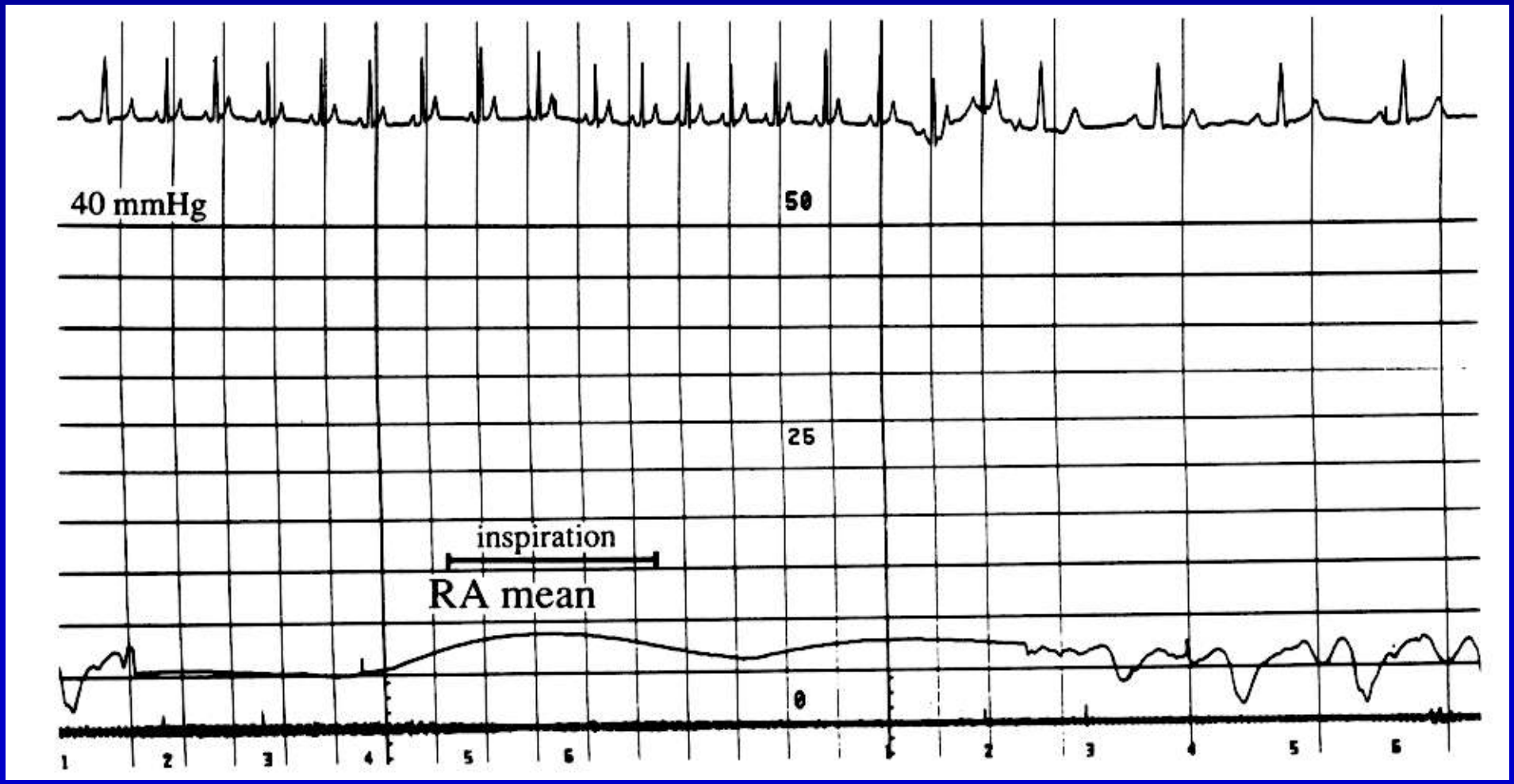
66 year old woman with edema



TV gradient is 11, and TV area is 1.5 cm2, patient underwent repeat TV replacement

Kern, p. 107

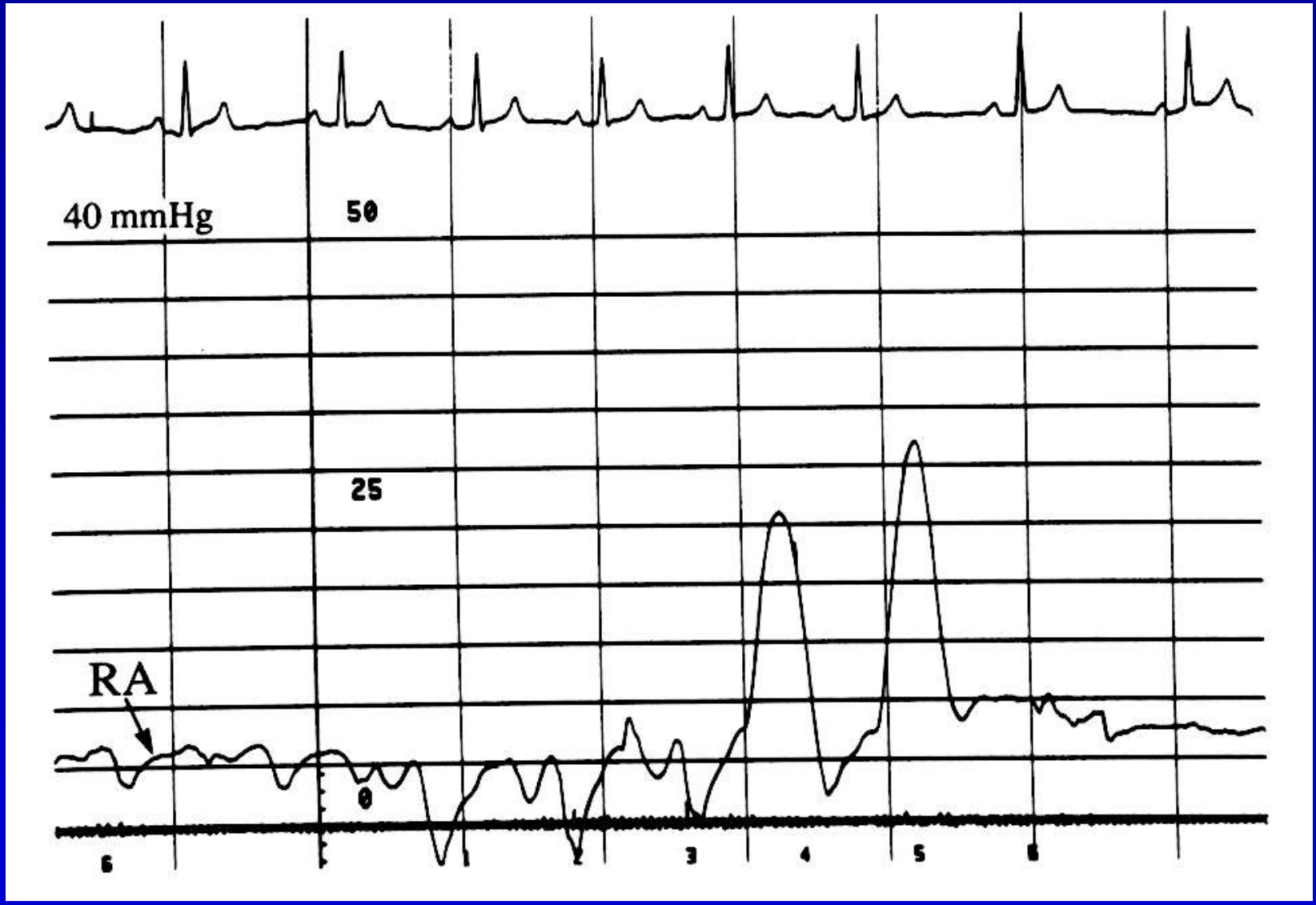
Kussmaul's Sign?



RA pressure rise in inspiration.

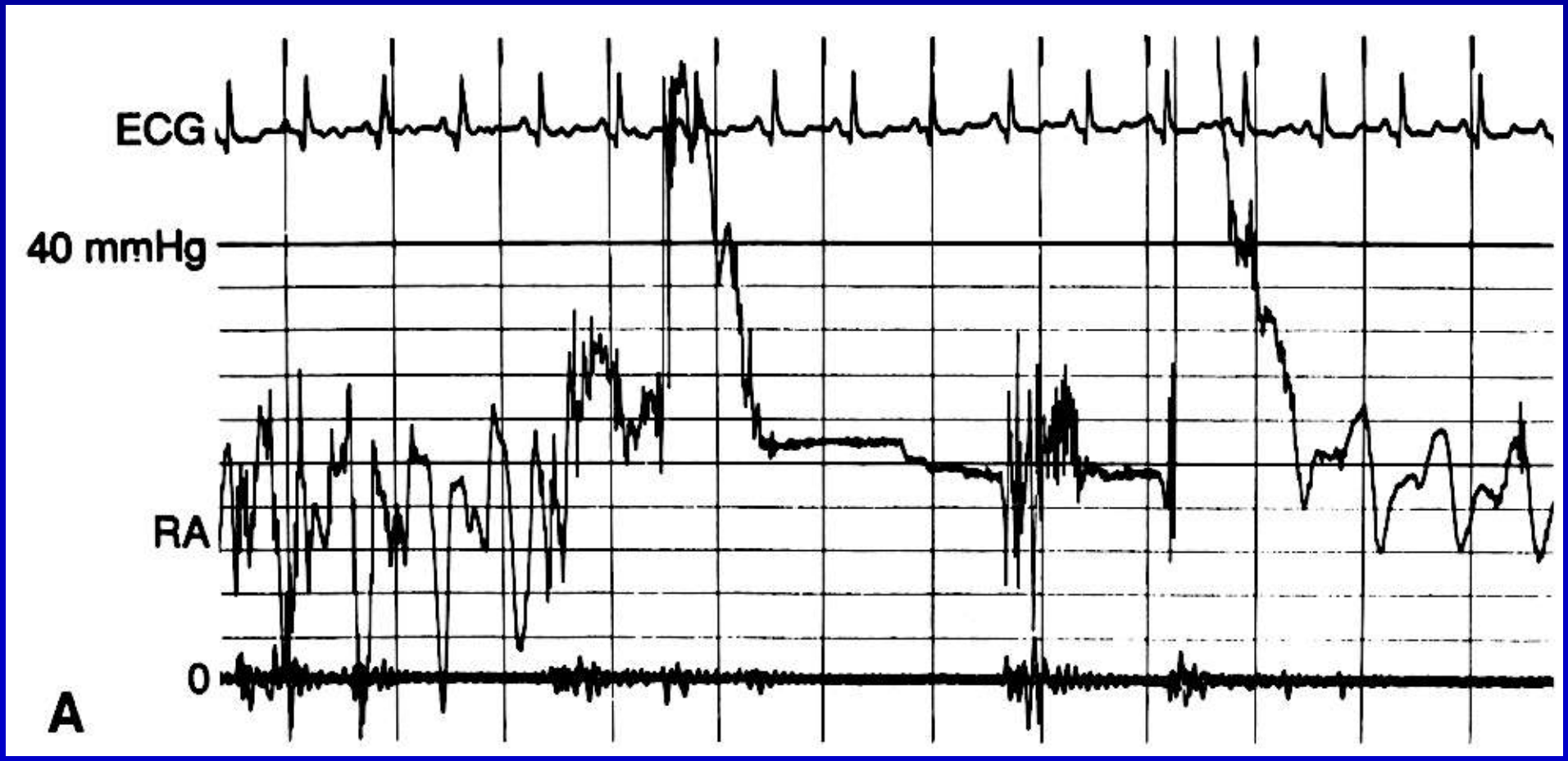
Kern, p. 108

Artifact Simulating Kussmaul's Sign



Kern, p. 108 Catheter slips into RV during inspiration

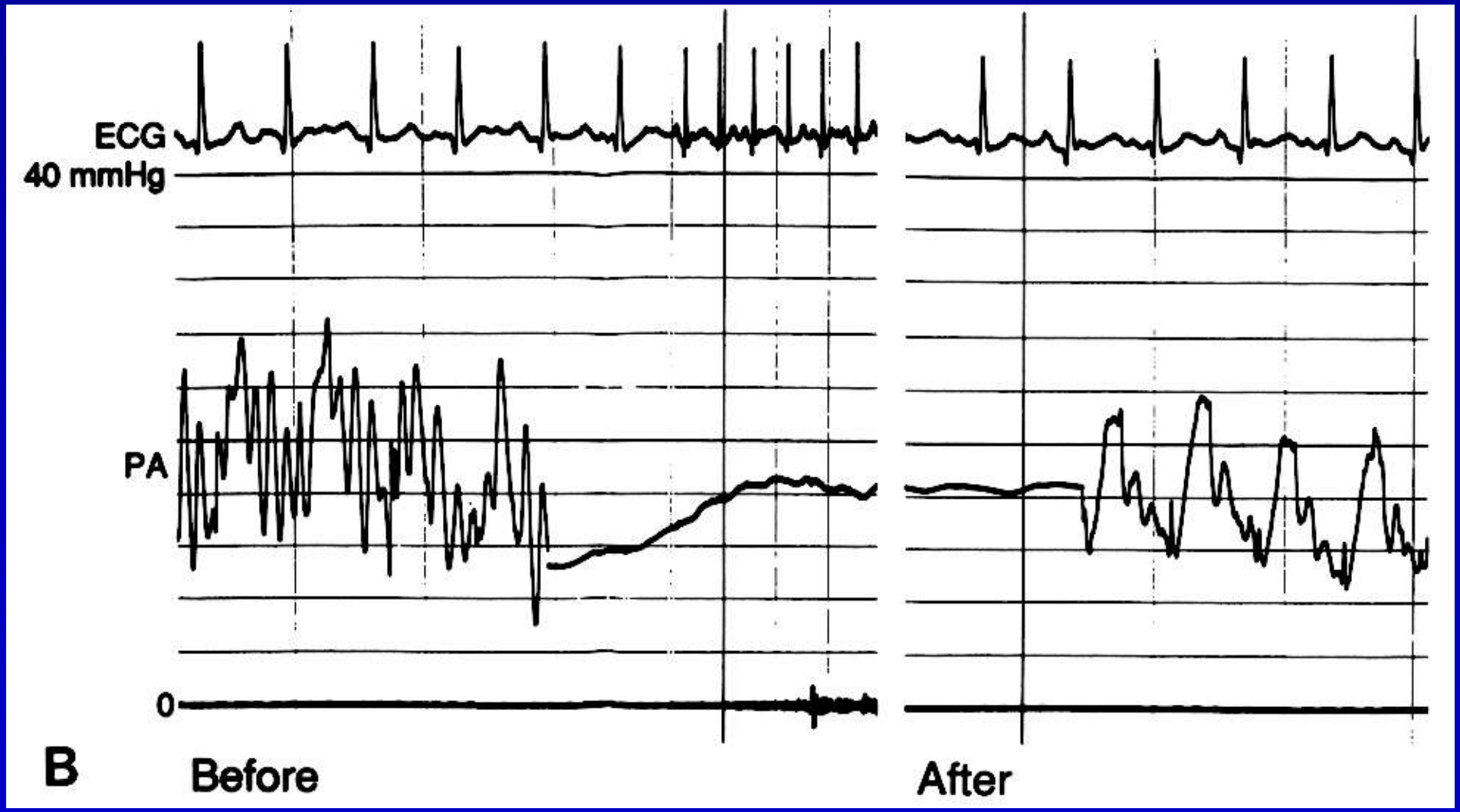
Excessive Catheter Fling



Correction by 50% saline and contrast solution

Kern, p. 109

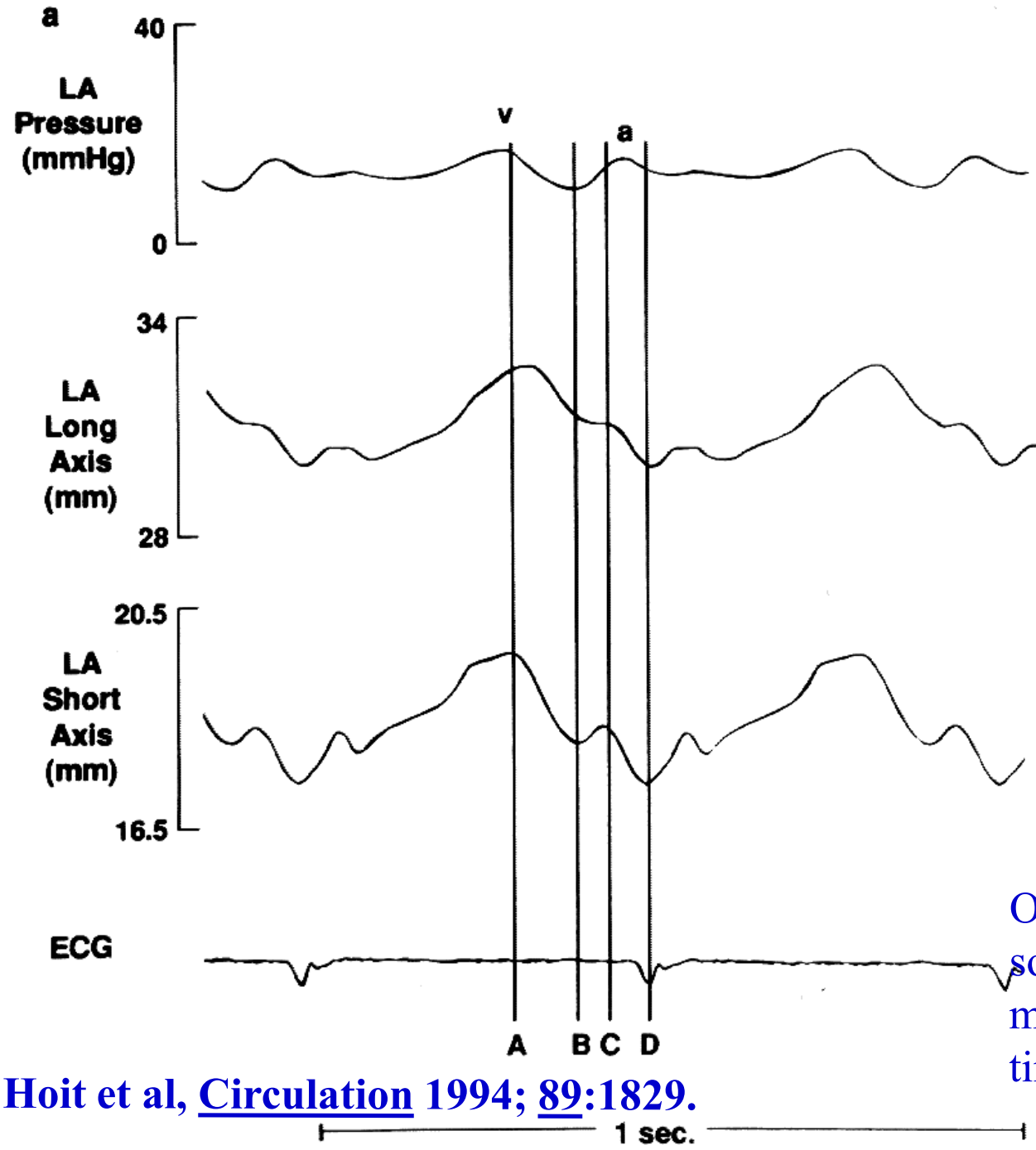
Excessive Catheter Fling

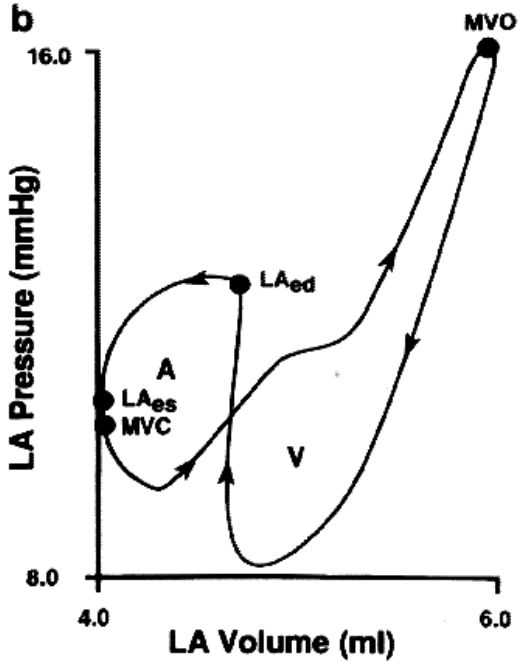


Correction by 50% saline and contrast solution

Kern, p. 109

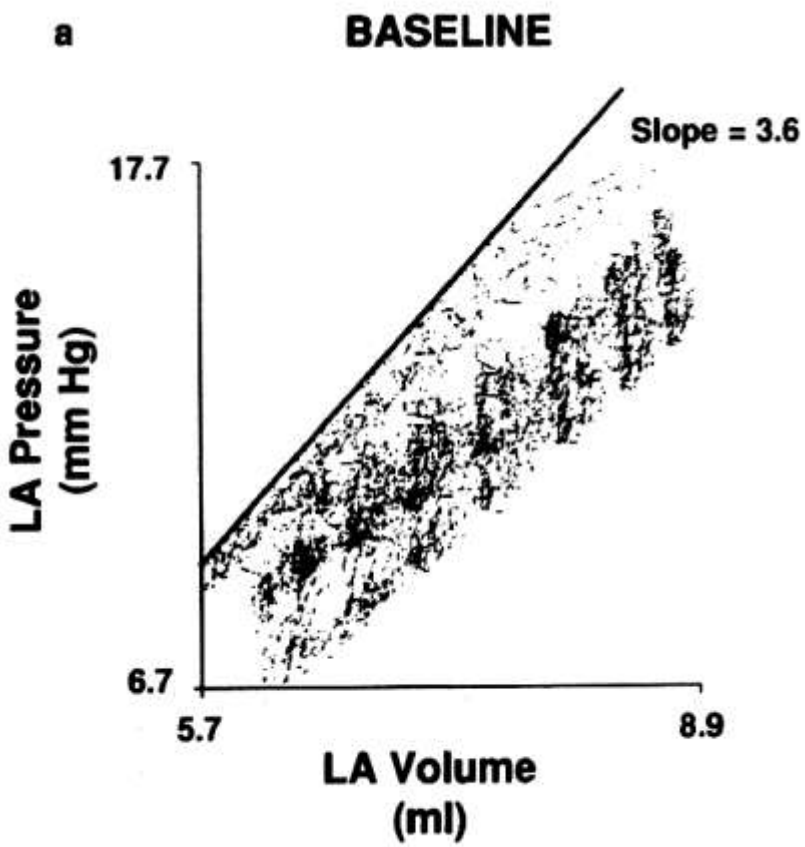
Atrial Pressure Volume Relation

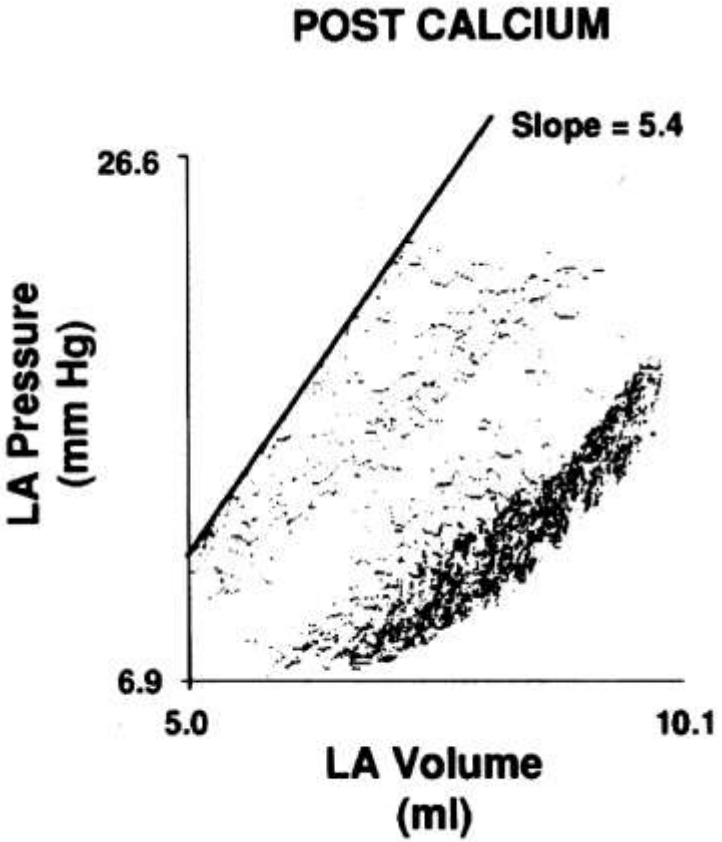


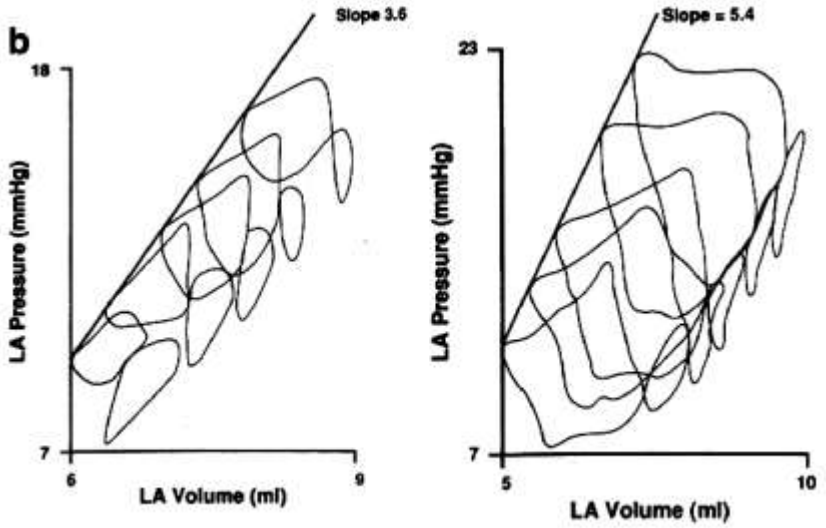


Open chest dog model with sonomicrometers and micromanometers evaluating time-varying elastance

Hoit et al, Circulation 1994; 89:1829.







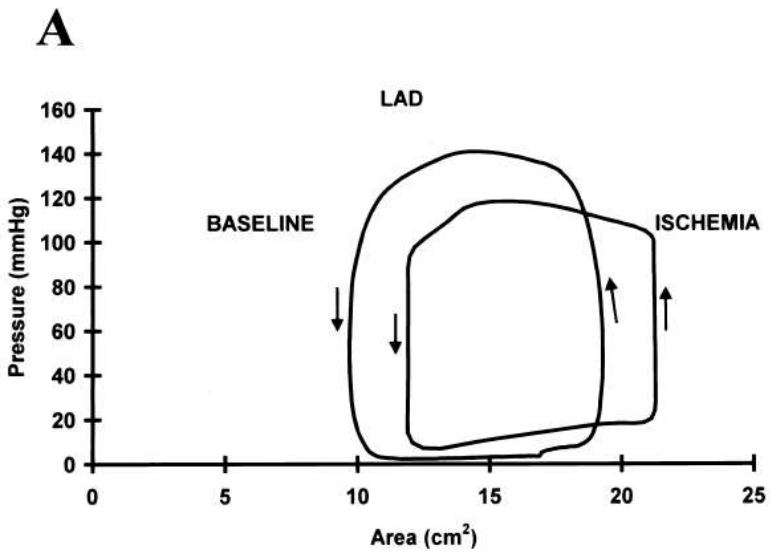
Left Atrial Pressure-Volume Relation

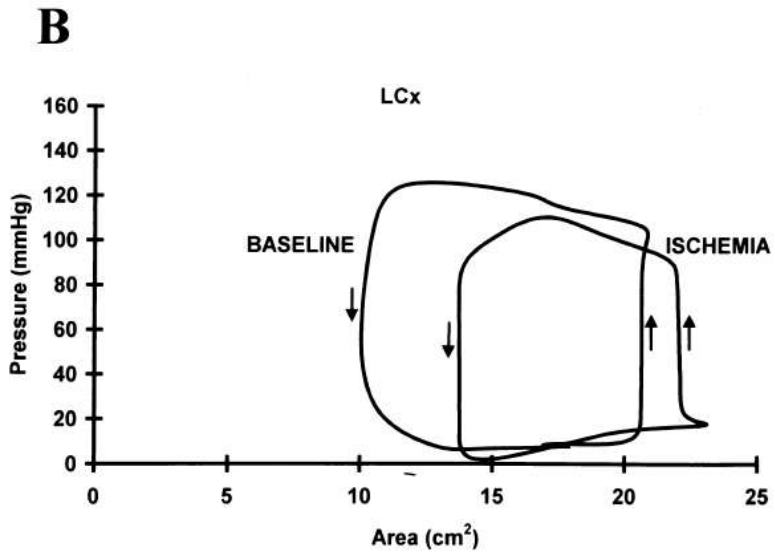
Hoit et al, Circulation 1994; 89:1829.

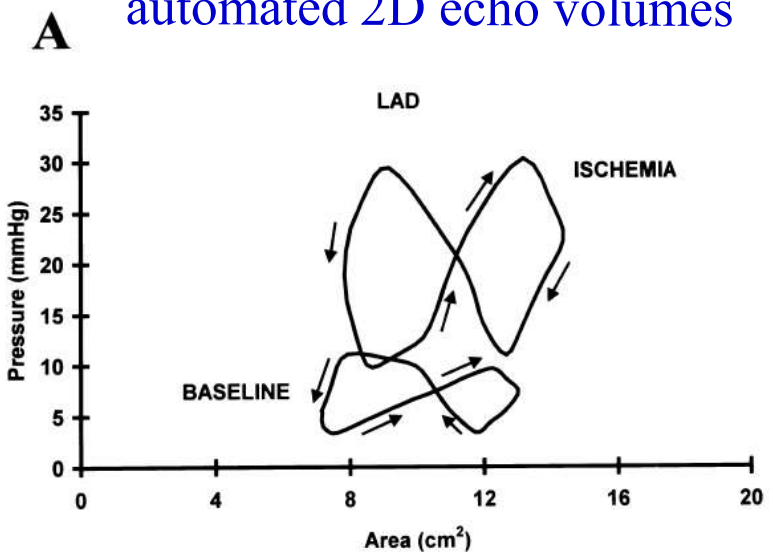
Atrial Function in Regional Ischemia

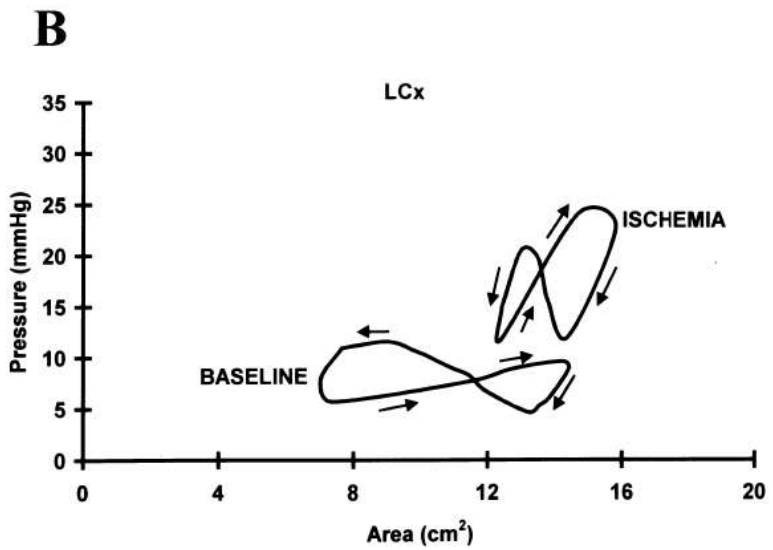
Stefanidis C et al. J Am Coll Cardiol. 1999;33:687.

CAD patients with micromanometer pressure and automated 2D echo volumes



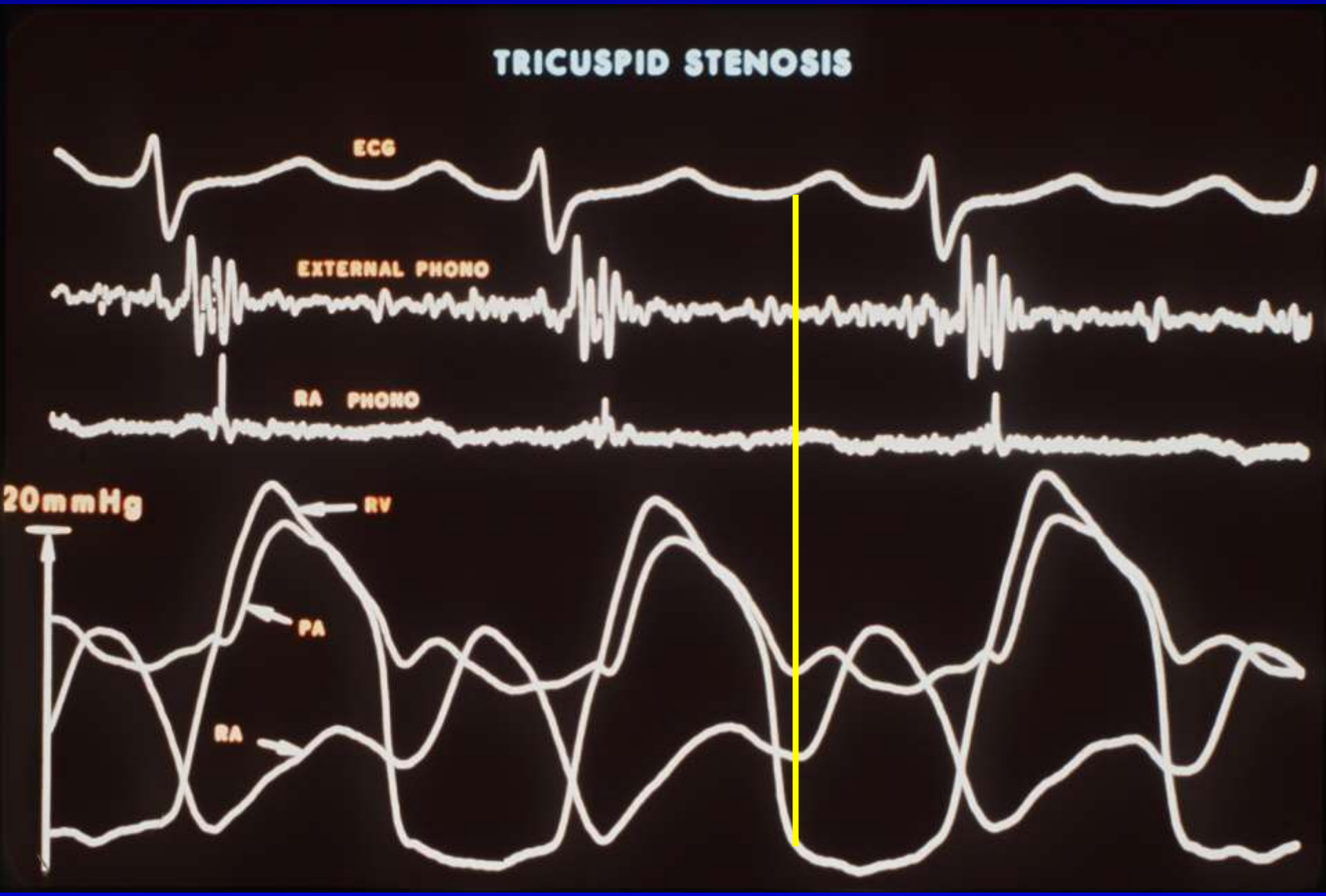






V Wave References

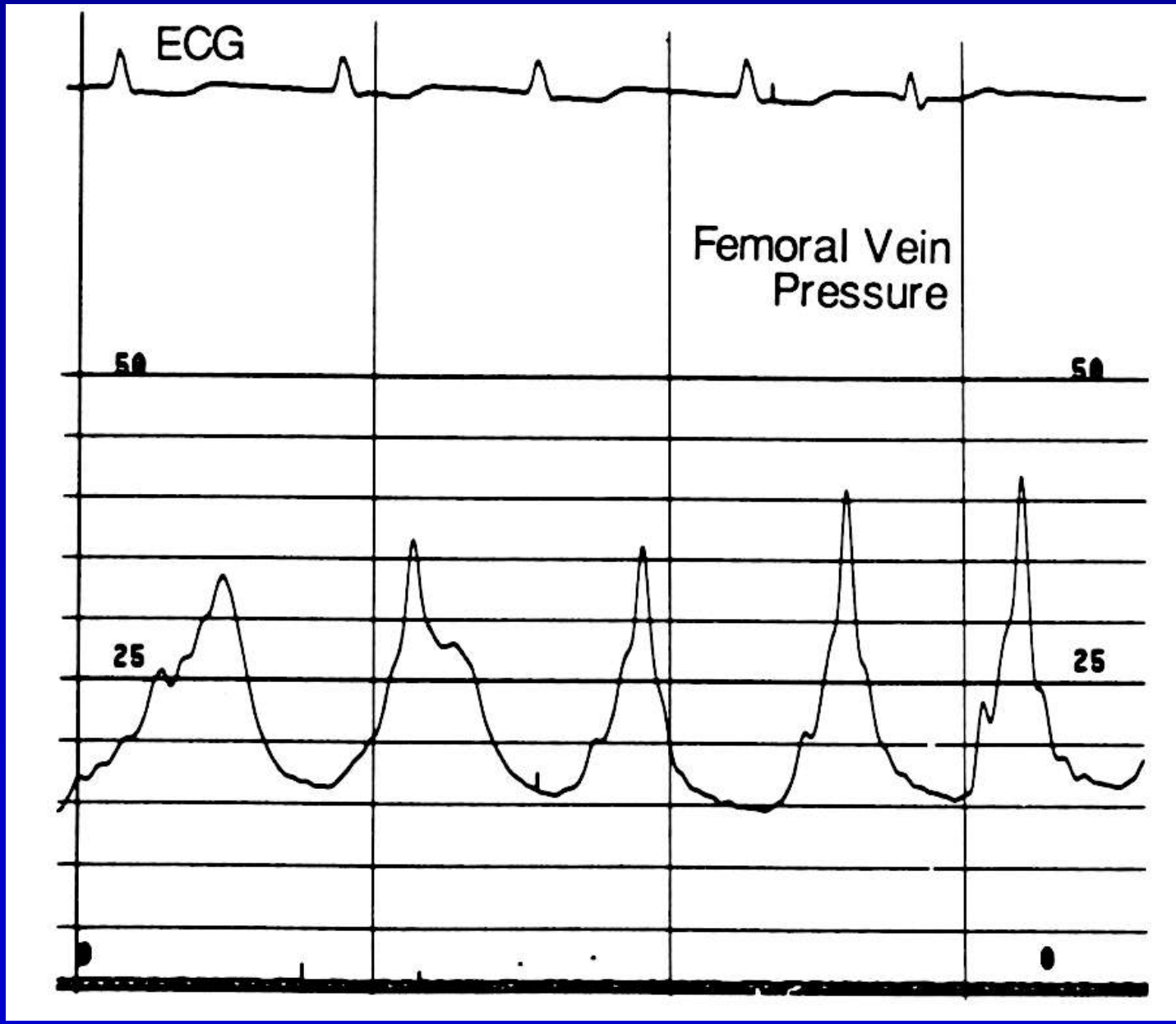
- Snyder RW, et al. Predictive value of prominent pulmonary arterial wedge V waves on assessing the presence and severity of mitral regurgitation. Am J Cardiol 1994;73:568-70.
- Lange RA et al. Use of pulmonary capillary pressure ot assess severity of mitral stenosis. Is true left atrial pressure needed in this condition. J Am Coll Cardiol 1989;13:825-9.
- Nishimura R et al. Accurate measurement of the transmitral gradient in patients with mitral stenosis: A simultaneous catheterization and Doppler echocardiographic study. J Am Coll Cardiol 1994;24:152-158.
- Alpert JS. The lessons of history as reflected in the pulmonary capillary wedge pressure. J Am Coll Cardiol 1989;13:830.
- Harshaw CW et al. Reduced systemic vascular resistance as therapy for severe mitral regurgitation of valvular origin. Ann Intern Med 1975; 83:312.
- Kern MJ. Hemodynamic rounds. 1999.
- Criley JM and Ross RS, Tampa Tracings, 1971


TRICUSPID STENOSIS
ECG
EXTERNAL PHONO
RA PHONO
20mmHg
RV
PA
RA

Severe Ascites and Dyspnea

39 year old woman.
V wave 32 mmHg.
Early RA-RV gradient equilibrates in the first 1/3 of diastole, torrential flow.
Rapid Y descent.

Femoral vein tracing.



Kern, p. 105

V wave Topics

- V wave physiology
- Pulmonary vein, pulmonary capillary, left atrium
- Vena Cava, right atrium