The V Wave

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Normal Hemodynamic Values

- Cardiac index 2.8-4.2 (mean 3.4 L/min/m²)
- 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/m²) EDV 50-90, ESV 15-25
- SVR 900-1400 (mean 1150 dyn*s/cm⁵)
- PAR 45-120 (mean 70)

LeWinter MM et al. Chapter 4, Hurst, 11th ed. 2004, p.90
## Normal Values Derived at BAMC

<table>
<thead>
<tr>
<th>Location</th>
<th>Nml</th>
<th>Maximal</th>
<th>Resp Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA,a</td>
<td>9</td>
<td>?12</td>
<td>2</td>
</tr>
<tr>
<td>RA.v</td>
<td>6</td>
<td>?12</td>
<td>2</td>
</tr>
<tr>
<td>RA,X nadir</td>
<td>3-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RA mean</td>
<td>6</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>LA,a</td>
<td>10</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>LA,v</td>
<td>12</td>
<td></td>
<td>3-4</td>
</tr>
<tr>
<td>LA mean</td>
<td>8</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>RV systolic</td>
<td>27</td>
<td>35</td>
<td>2-3</td>
</tr>
<tr>
<td>RVED</td>
<td>5</td>
<td>7</td>
<td>1-2</td>
</tr>
<tr>
<td>LV systolic</td>
<td>120</td>
<td>135</td>
<td>4-8</td>
</tr>
<tr>
<td>LVED</td>
<td>10</td>
<td>12</td>
<td>3-4</td>
</tr>
<tr>
<td>PA systolic</td>
<td>22</td>
<td>30</td>
<td>3-4</td>
</tr>
<tr>
<td>PA diastolic</td>
<td>12</td>
<td>15</td>
<td>3-4</td>
</tr>
<tr>
<td>PA mean</td>
<td>15-17</td>
<td>18 (20)</td>
<td>4-5</td>
</tr>
</tbody>
</table>
Normal Left Ventricular – Left Atrial Relationship
Normal Left Heart Waveforms
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

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

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

Mitrail Stenosis

Atrial Pacing Pre-RNBMV

Atrial Pacing Post-RNBMV

RNBMV – retrograde nontransseptal balloon mitral valvuloplasty

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

Right Heart Pressures with Goodale-Lubin

Grossman, 6th ed, 2000; p. 108
Simultaneous LA-PCW Pressures

Each time mark is 0.05 sec

Acute Mitral Regurgitation
Acute Mitral Regurgitation

Hurst, 2004, p.1689
Effect of Afterload reduction on V wave

Pressure (mmHg)

Time (sec)

Nitroprusside

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

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

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

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

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

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

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Numeric plots of change in V and D with different alterations of state, with systemic vascular resistance showing steeper slope, that is more of a change in V wave considering the change in D wave.
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
62 yo man with aortic stenosis… LA is 22 (no MR), RA is 10
Interpret the waveforms
RHEUMATIC VALVULAR HEART DISEASE - TRICUSPID INSUFFICIENCY
(PROSTHETIC MITRAL VALVE)

ECG
EXTERNAL PHONO S-1 S-2 OS

mHg
PA RV RA

RESP 1 SECOND
Dysrhythmia and RA pressure

Kern, MJ, 1999, p. 103

66 year-old man after MI
RA large V wave in TR and AF

Comparison of RA and LA V waves

Compensated CHF, unusually narrow “a” wave suggests artifact
50 year old woman. Rhythm? Note Y descent. TS?
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

49 year old woman, small diastolic gradient is significant

Arrow points to C wave
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
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


CAD patients with micromanometer pressure and automated 2D echo volumes
V Wave References


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Severe Ascites and Dyspnea

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Femoral vein tracing.
V wave Topics

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