How to Utilize Respiratory Manouvers in Echocardiography
Practical Applications in Daily Practice

Karthik Ananthasubramaniam, MD FACC FASE FASNC
Associate Professor of Medicine
Wayne State University
Director, Echocardiography and Nuclear Cardiology/PET Laboratory
Henry Ford Hospital, Detroit MI

kananth1@hfhs.org

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Objectives

Outline effects of respiration on heart

Outline how respiration can affect 2d, doppler imaging

Tips for better accquisition

Understand role of Valsalva manouver in echo

Use of respiratory in different cardiac conditions

Respiration : Effects

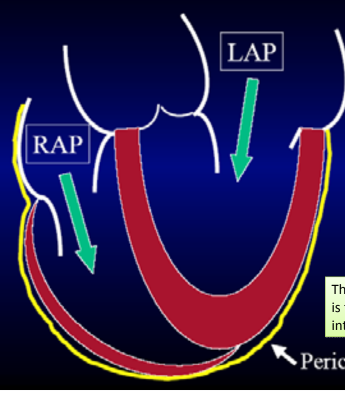
Physiologic effects of respiration are secondary to

1. Variations in intra-thoracic and intra-abdominal pressure
2. Changes in systemic and pulmonary venous return
3. Intra pericardial pressure
4. Pericardial constraint
5. Ventricular interdependence

Anatomic effects of respiration are due to

1. Inflation of lungs and interference
2. Drop out of lateral shadows
3. Cardiac translation
4. Descent of the diaphragm

Normal RV-LV Filling



Low intra-pericardial pressure allows intra-thoracic pressure to be reflected in the intracardiac pressure

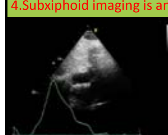
Therefore diastolic filling pressure is the result of LV stiffness and intra-pericardial pressure

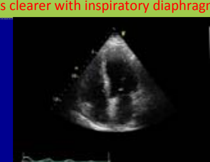
Respiration and Image Quality

With inspiration :

1. Increase in AP diameter
2. Lung inflation
3. Rotation and posterior motion of heart
4. Subxiphoid imaging is an exception ; heart images clearer with inspiratory diaphragm descent

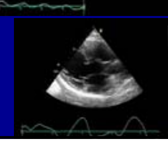
Less heart available for imaging



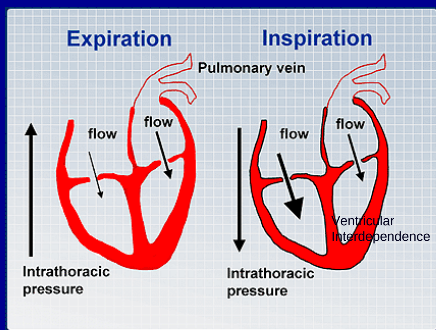


With expiration :

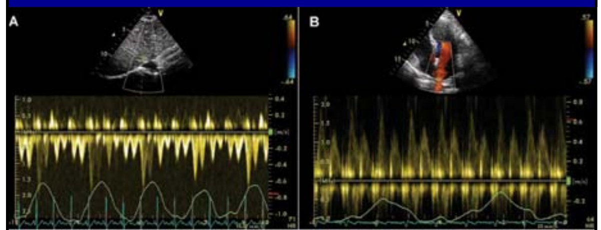
1. Lung deflation (particularly in steep left lateral position with left arm up)



Physiology of Respiration



Respiration and Doppler of Veins



Hepatic vein doppler
Sig inspiratory increase of S and D
SVC flow mimics HV doppler changes

Pulmonary vein doppler
Minimal resp changes in S
but d and VTId increase

Respiration and Echo Measurements

Inspiratory decrease in LV end diastolic dimensions as measured by M-mode

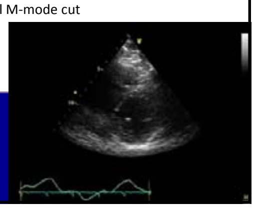
This may sometimes explain discrepancies between centerline PSAX measurements and those obtained by M-mode

Possible reasons:

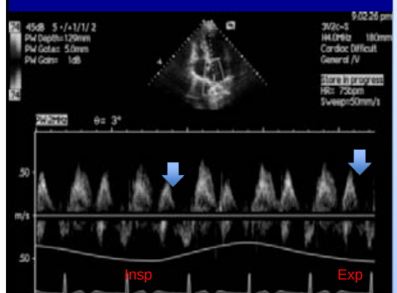
1.Heart moves medially during inspiration= ? Tangential M-mode cut

2.Decrease in LV volumes in inspiration
(preload reduction and increase afterload or impedance to LV emptying)

How to measure : suspended quiet respiration make sure to instruct patients to avoid Valsalva during held expiration as it degrades image quality



Resp and Pulmonary Venous flow



s and VTIs not affected

d and VTId increase with exp
Hence s/d < 1 and VTIs/VTId < 1 in exp

Mechanisms in health

Left right interactions

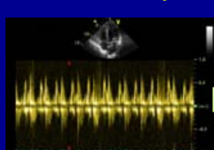
Diastolic dysfunction causes higher LV diastolic pressures

So intra-cardiac interactions of septa in resp decreased

So d and VTId do not vary with insp and exp

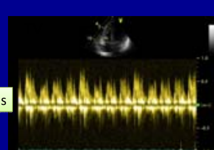
Lack of variation a clue

Respiration and Doppler of AV and Systemic Valves



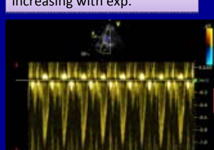
Mitr

Tricus



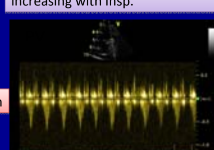
Transmitral v. varies by <10%, increasing with exp.

Tricuspid v. varies by <20%, increasing with insp.



Aortic

Pulm



Respiration And Doppler Issues

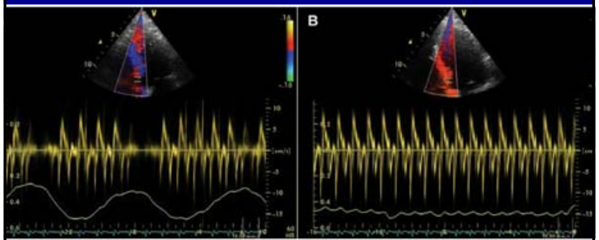
Fixed doppler sampling errors can occur during respiration due to change in heart position and diaphragmatic traction

Parallel positioning and avoidance of angle of incidence issues is key. Less than 10% error is most preferable given the quadratic relationship of pressure and velocity

End expiration apnea most preferred for doppler sampling

Similar sampling issues affect tissue doppler

Respiration and Tissue Doppler



During normal respiration | During end expiratory apnea

Sample volume can move with respiration. Best obtained with held expiration

Respiration , IVC and Echo RAP: ? Time for Reappraisal

Brennan et al : JASE 2007
RAP measured from IVC in subcostal view and compared to RHC. This study questions using tight cutoffs of 5 mm to define RAP based on IVC

Overall IVC size 2cm served as the most optimal cutoff for RAP > or < 10 (sens 73% spec 85%)

IVC collapsibility index of 40% was the best predictor for response (sens 74% spec 84%)

Respiration and IVC

Minimal size observed in end inspiration

<u>Influenced by patient position :</u>

Largest in right lateral position

Intermediate in supine position

Smallest in left lateral position

Normal ranges : 1-2 cm (upper normal range ASE guidelines 1.7 cm)

Can be large and minimally reactive in young patients, athletes can have large IVC and normal collapsibility index

Sniff test captured in real time and m-mode 3-5 loop rhythm capture will be helpful . M-mode cursor to be placed away from IVC-RA junction

A New Classification for RAP

(1) High collapsibility with a small or normal-sized IVC; RAP is very likely low (<5 mm Hg).

(2) High collapsibility with a large IVC or normal collapsibility with a small/normal-sized IVC; RAP is probably between 0 and 10 mm Hg

(3) Normal collapsibility with large IVC; RAP is 10 to 15 mm Hg

(4) Low collapsibility with a large IVC; RAP is clearly high (10–20 mm Hg)

(5) RAP in patients with low collapsibility and a normal-sized or small IVC should be interpreted as indeterminate.

Brennan et al : JASE 2007

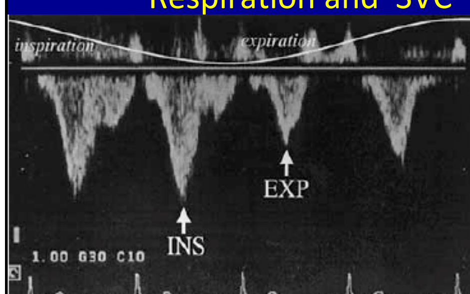
Respiration and IVC

IVC Diameter	% Collapse with Sniff	Estimated CVP
<1.2 cm	Full collapse	0 mmHg
1.2-1.7 cm	>50% collapse	1-5 mmHg
>1.7 cm	>50% collapse	6-10 mmHg
>1.7cm	<50% collapse	11-15 mmHg
>1.7 cm	0% collapse	>16 mmHg

Dilated IVC in vented patients does not mean elevated RAP. Collapsed IVC (>50%) indicates dehydration in vented patients

Specificity for predicting RAP increases when IVC size is measured at end expiration by M-mode AND at end disatole

Respiration and SVC



Normal : Systolic forward flow = RA relaxation during RV contraction
Diastolic forward wave = rapid RV filling wave
Vary with respiration with both waves higher during inspiration than expiration

Mechanism of Flow Changes in SVC Possible clue to Pul HTN in COPD

SVC is an intra-thoracic structure : Interrogation is from right supraclavicular fossa with doppler
PW sample volume of 2mm.

Changes in RA pressure following change in pleural pressure causal SVC flow variations

Expiratory systolic flow in SVC is a measure of RA flow reserve

In Pul HTN : RV filling is restricted----- RA pressure is elevated and------- SVC forward variation is blunted

In Pul HTN : RA preload reserve is enhanced to compensate for RV dysfunction and hence SV expiratory forward flow velocity is increased

Hence SVC interrogation would be a useful adjunct in patients with significant lung disease where TR jet is not well seen or minimal to no TR is present precluding good assessment of PASP

Valsalva in Diastolic Function

a. **Need to instruct patients correct how to do it. To avoid forceful deep inspiration prior to the forced expiration.**

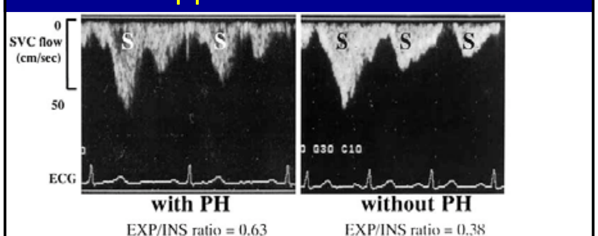
b. Forced expiration against closed nose and mouth.

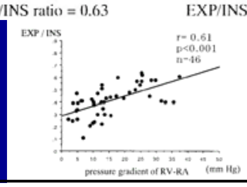
c. **Useful to clarify pseudonormal mitral inflow patterns.**

d. In normal patients if the E wave drops by 20cm/sec that is a good effort useful to interpretation. E/A ratio remains above 1 despite the change in patients with normal diastolic function

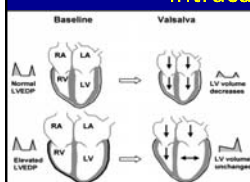
e. A E wave drop > 50 cm/sec is highly specific (100% spec) for elevated filling pressures accompanied by reversal to impaired relaxation pattern to confirm pseudonormal pattern although lower levels may also indicate the same diagnosis

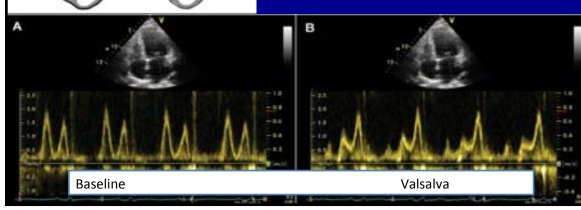
SVC Doppler Index and Pul HTN





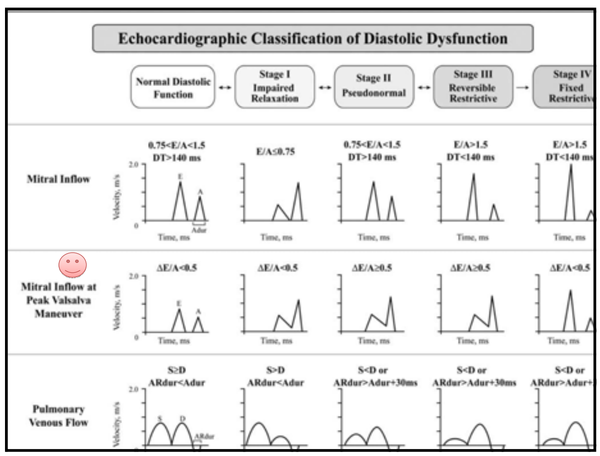
The Valsalva Manouever : Its Effects on Intracardiac Volumes

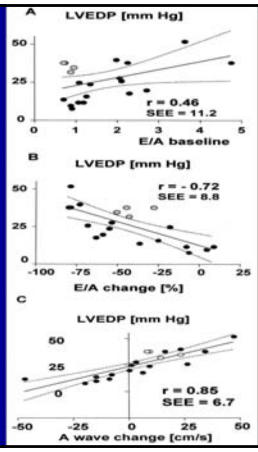




The Valsalva Manouver

- Phase 1 start strain : increased BP , transient increase venous return
- Phase 2 strain maintained : decrease BP, pulse pressure and sinus tachycardia
- Phase 3 strain release : progressive fall in BP
- Phase 4 post release phase : overshoot of BP and reflex bradycardia





Correlations between LVEDP and the baseline E/A ratio (A),

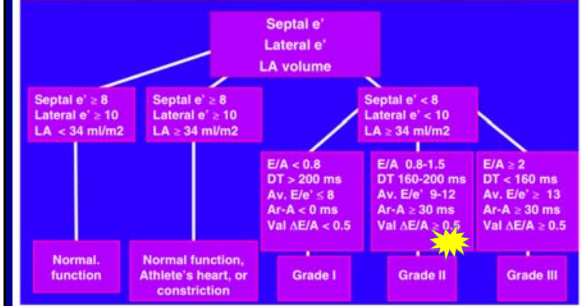
the change of the E/A ratio during Valsalva (B), And

the change of the A wave during Valsalva (C).

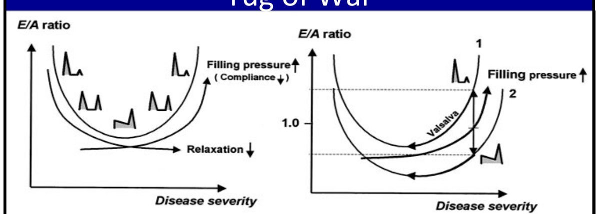
Patients with a baseline E/A ratio of <1 (impaired relaxation pattern) despite substantially elevated LVEDP are represented by the gray circles.

Schawammenthal et al AJC 2000

Practical Approach to Grade Diastolic Dysfunction



Relaxation and Compliance Tug of War

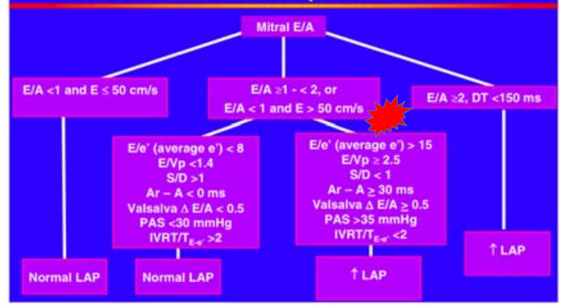


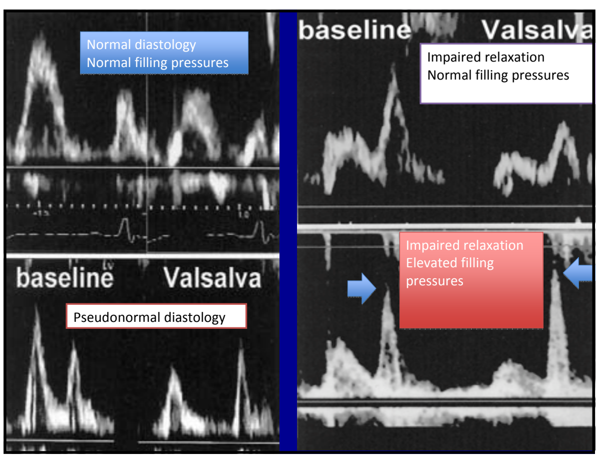
As diastolic dysfunction progresses : 2 scenarios can play out or co-exist

Impaired relaxation gives way to increased LV stiffness (decreased compliance)

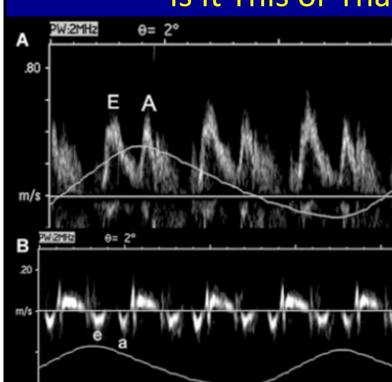
Severely impaired relaxation persist despite progressive worsening of compliance

Estimation of Filling Pressures in Patients with Depressed EF





Is It This or That ?



Beat to beat variation of E/A with respiration

E/A < 1 in Insp

E/A > 1 Exp

DT shorter in Exp than Insp

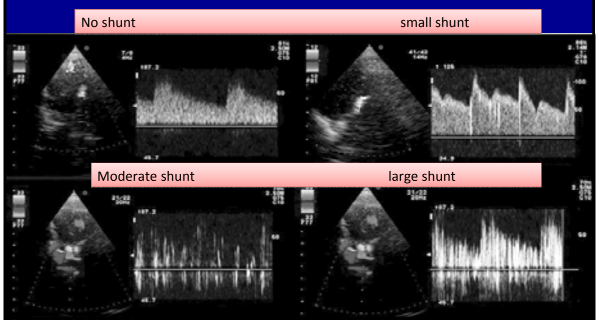
No effects of resp on A wave

This pattern associated with mpaired tissue doppler

Could be a clue to diastolic dysfunction

Respiration and PFO Detection

TEE considered highly sensitive even more than TCD



Detection of PFO
SPARC Study Protocol

- 2 rest injections
- 2 injections with cough
- 2 injections with Valsalva

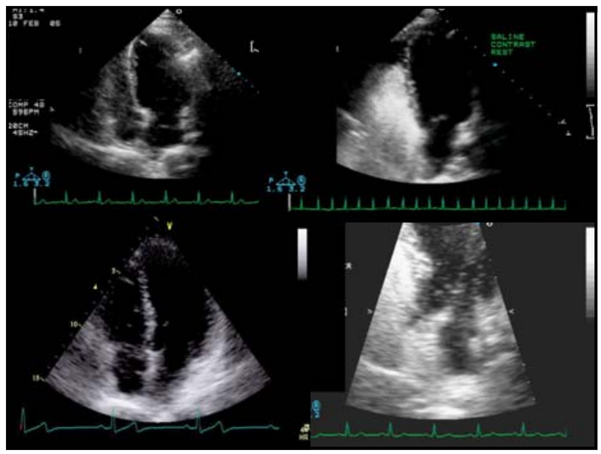
TEE PFO and Respiration

Cough or Valsalva is widely employed
Both false negatives and false positives can occur related to the respiratory effort

False negative : poor effort in combination with sedation or lack of understanding of how the Valsalva is to be done

Solution : instruct pt prior to TEE. A good idea would be to perform a bubble study with Valsalva prior to sedation and intubation both as a practice run and as check to pt compliance and understanding of what is expected

False positive : Spurious contrast misinterpreted as "shunt"
small pulm AV malformation causing bubble appearance



Detection of PFO
Methodologic Issues

- Number of injections
- Use of maneuvers → Valsalva, Coughing
- Femoral approach
- Use of color Doppler
- Harmonic imaging (TTE)
- Transmitral Doppler

Spurious contrast : Snow Storm

Has been described with cough and Valsalva maneuver

Has been described with TTE but most often TEE

Valsalva -------blood pooling in pulmonary veins------ rouleax formation

Release of Valsalva ------------ drops LA pressure ---------- rush of pulmonary vein blood into LA

Saline Bubbles	Spurious contrast
bright and localized onset	faint and weak intensity
Stronger echodensity	Weaker echodensity
Persistent	evanescent

Spontaneous " spurious Contrast " likley due the combination of rouleaux and cavitation as blood enters LA after Valsalva release

Spurious Contrast, SEC and Respiration

SEC (Spontaneous echo contrast) versus	Spurious contrast
Low flow states	No specific condition
Spontaneous occurrence	** Only with cough / valsalva
Gain dependent	Gain dependent

Solution:

1.Check for exit of bubbles with Valsalva release from septum or pulmonary vein. . Make sure bubble study protocol allows for adequate cine loop capture focusing on septum/RUPV in bicaval view with definitive capture post Valsalva release

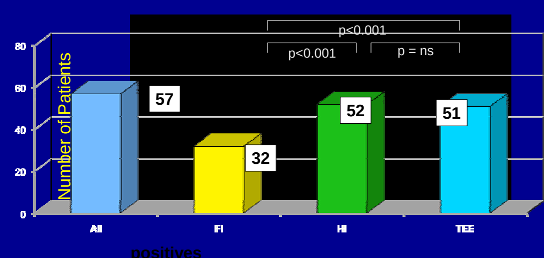
2. If septum normal with no clear PFO tunnel and no definite exit documented, but apparent bubble appearance in LA noted suspect Spurious Contrast.

3.Allow saline to clear and do a Valsalva /release cine without any right heart bubbles to look for spurious contrast

Detection of PFO
Causes of False Positive TEE

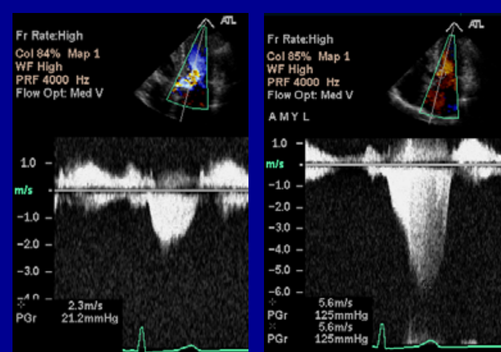
- Transpulomonary microbubbles
- Extraneous background echoes/noise precipitated by Valsalva
- Pulmonary A-V malformation

Patients with Atrial Shunts Detected
by
Three Different Imaging Modalities



Kuhl et al JACC 34:1823(1999)

HOCM and Valsalva

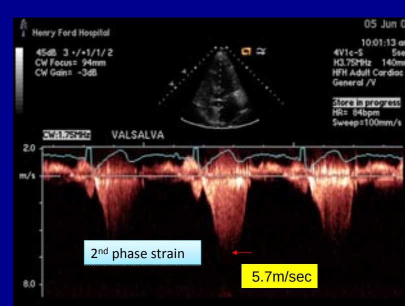


Detection of PFO
Causes of False Negative TEE

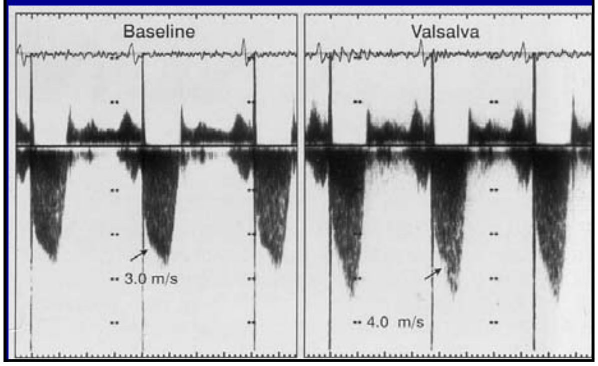
- Inadequate visualization (uncommon)
- Insufficient number of injections
- Elevated LA pressures may prevent left-to-right passage of contrast
- IVC-directed flow along IAS prevents impingement of antecubital bubbles against IAS
- Improperly performed Valsalva maneuver

Common Provocations

- Valsalva

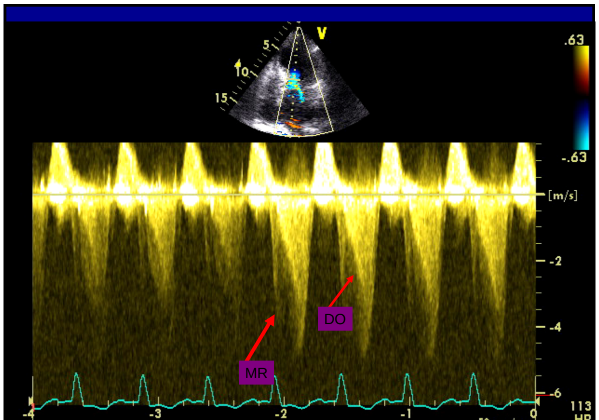


Gradient in HCM with Valsalva

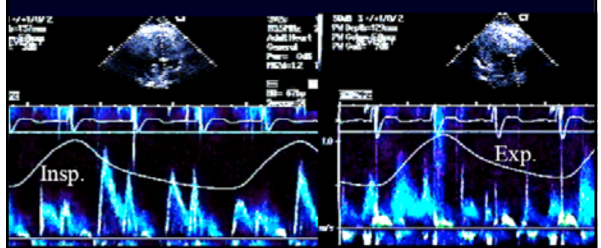


2D Echo Features

- Moderate to large pericardial effusion 2 cm or greater (loculated/circumferential)
- Swinging heart motion pattern (not always present)
- Right atrium collapse (late diastole or early systole) >30% inversion
- Right ventricle collapse (early diastole) .05 sec after MVO
- Left atrial collapse (late diastole or early systole)
- Left ventricle collapse (early diastole)
- Dilated inferior vena cava w/out collapse on inspiration
- Dilated hepatic veins >1.1 cm
- Paradoxical septal motion of the IVS or inspiratory bounce (towards the LA)
- Inspiratory bounce of IAS (towards the LA)



Cardiac Tamponade-Respiratory Changes



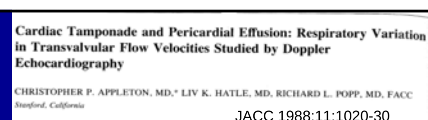
Mitral Inflow

Tricuspid Inflow

The changes are seen on the first beat of inspiration or expiration

Echo Changes in Cardiac Tamponade

1. RA and RV expand with leftward shift of ventricular and atrial septa
2. Reduced aortic and mitral valve opening time
3. Increased RV and reduced LV stroke volume
4. Decreased aortic and mitral flow velocities
5. Sharply increased tricuspid and pulmonary flow velocities
6. Decreased transmitral Doppler E/A ratio and increased transtriscupid E/A ratio.



Cardiac Tamponade and Pericardial Effusion: Respiratory Variation in Transvalvular Flow Velocities Studied by Doppler Echocardiography

CHRISTOPHER P. APPLETON, MD,* LIV K. HATLE, MD, RICHARD L. POPP, MD, FACC

Stanford, California

JACC 1988;11:1020-30

20 normal patients

7 patients with tamponade

- Left Heart
  - Normal
    - IVRT, MV E vel, MV A vel <10%
  - Tamponade
    - IVRT ↑ 85%
    - MV E vel ↓43%
    - MV A vel ↓25%
- Right heart
  - Normal
    - TV E and A vel <25%
  - Tamponade
    - TV E vel ↑85%
    - TV A vel ↑58%

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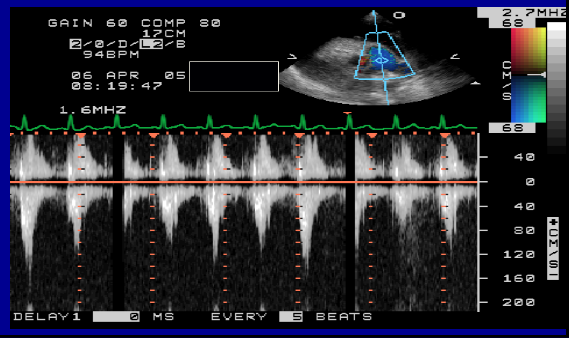
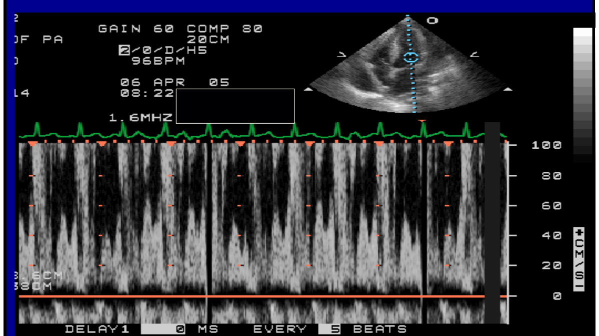
Percentage change from first beat of expiration to first beat of inspiration.

Patient Group	IVRT (ms)	M1 (cm/s)	T1 (cm/s)	LVET (ms)	Ao (cm/s)	PA (cm/s)
Normal and post Tap (n=20)	2	-4	14	-3	-4	5
Tamponade (n=7)	85	-43	85	-21	-26	40
Eff – Variation (n=8)	32	-31	74	-9	-17	49
Eff – No Variation (n=7)	3	-5	32	-2	-4	6

Respiratory variation of pulmonary outflow > 30%



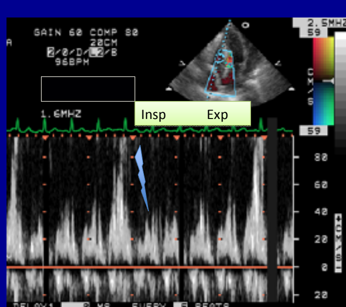
Respiratory variation of mitral inflow > 25 - 30%



Respiratory Variation

- Patients with Tamponade have marked variation in flow velocities.
- Some patients with large effusions without tamponade physiology have variation in flow velocities.
- These patients have increased pericardial pressures and an element of hemodynamic compromise
- Velocities return to normal following pericardiocentesis.

Respiratory variation of tricuspid inflow > 50%



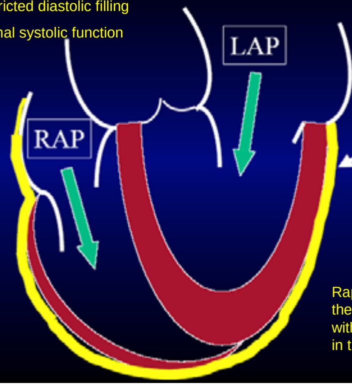
Diferential Diagnosis of Respiratory Variation

- COPD
- Pericardial Constriction
- Severe Tricuspid Regurgitation
- RV infarction

Constrictive Pericarditis

Restricted diastolic filling

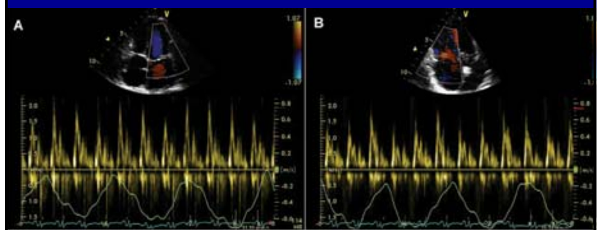
Normal systolic function



Thickened Pericardium ac as a shell that limits ventricul expansion

Rapid filling occurs in the first 1/3 of diastole with little filling occurring in the last 2/3

Respiration, Constriction and AV Valve Flows



Diastolic septal bounce with inspiration

- Venous return increases leading to increased RV volume
- Total cardiac volume constrained by pericardium
- Interventricular dependence leads to septal shift

With permission, Dunitz 2000

Respiration , Constriction and SVC Flow

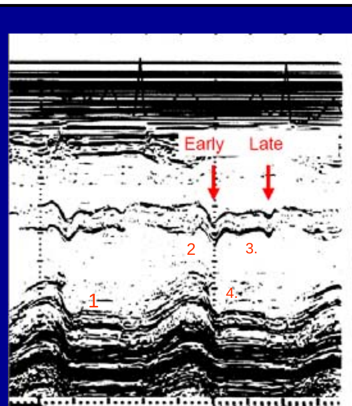
1.Flattened posterior wall motion

2.Paradoxical septal motion

3.Septal bounce

4. Rapid diastolic filling

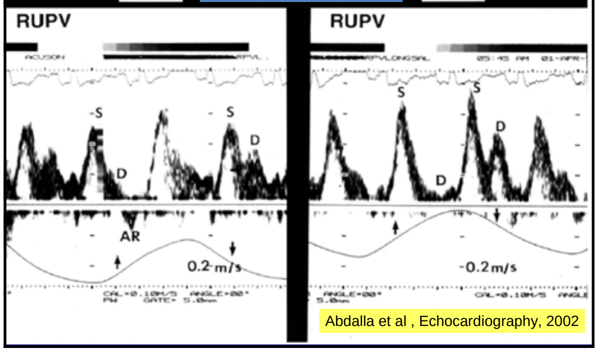
Thickened pericardium



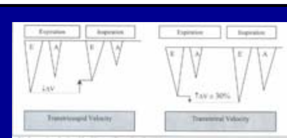
- PW Doppler mitral inflow: high E velocity, E/A ratio > 2, short E wave deceleration time (EdT < 160 ms); inspiration: decrease E velocity >25%, prolonged IVRT >25%; expiration: opposite changes (Figure 6A)
- PW Doppler tricuspid inflow: E>A; inspiration: increased tricuspid E velocity >35%, characteristic phenomenon increased TR velocity (Figure 6B)
- PW Doppler recordings of hepatic vein flow: inspiration-minimally increased S and D; expiration: decreased diastolic flow/exaggerated atrial reversal waves (Figure 7)
- PW Doppler recordings of pulmonary vein flow: S/D ratio = 1, inspiration: decreased PV S and D waves, expiration: opposite changes
- SVC Doppler usually shows a diastolic dominant pattern, minimal respiratory variation as right atrial pressure is constantly elevated throughout the respiratory cycle by the thickened, constraining pericardium
- Inspiration: aortic velocity decreases (-14 ± 5%), pulmonary artery velocity increases (16 ± 4%)
- Dilated IVC with reduced inspiratory change in diameter

Constrictive Pericarditis
Fluid Challenge

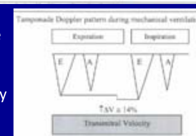
Pre | When respiration dosn't work | Post



Abdalla et al , Echocardiography, 2002

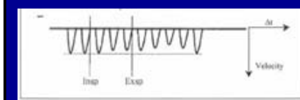


- Normal
  - IPPV* will produce opposite respirophasic changes in velocity
  - Hypovolemia increased these changes further



Tamponade
- **MV opposite direction and attenuated**

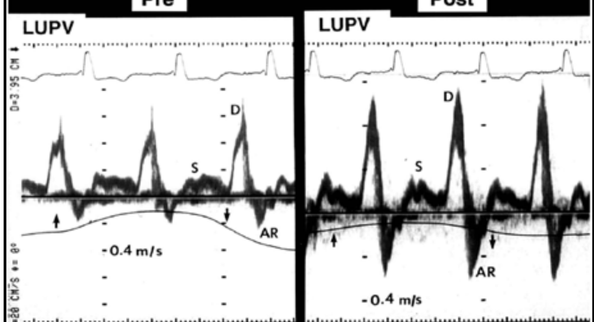
Constriction
- **E vel increases with inspiration 18%**
- **Pulmonary vein D wave increased 28% with inspiration**



Intermittent Positive Pressure Ventilation

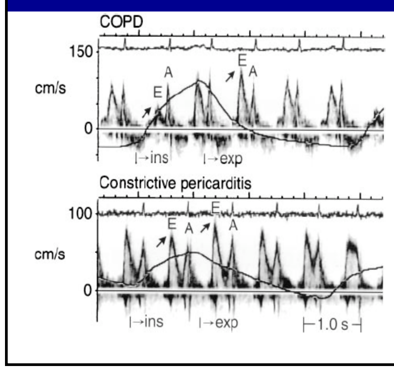
Restrictive Cardiomyopathy
Fluid Challenge

Pre | Post



Abdalla et al , Echocardiography, 2002

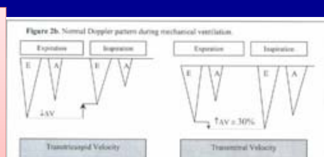
Respiration and Constriction Vs COPD



More dramatic change in forward velocities with Insp in COPD than CP

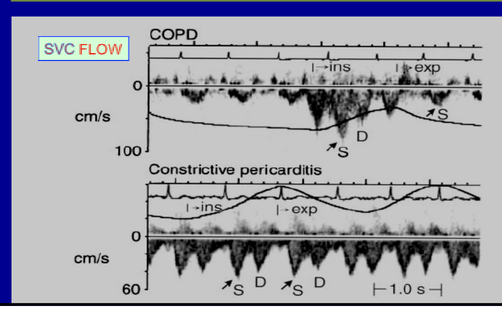
Intermittent Positive Pressure Ventilation

- Normal
  - IPPV will produce opposite respirophasic changes in velocity
- Hypovolemia increased these changes further



Respiration : Constriction Vs COPD

Systolic forward velocity varies > 20 cm/sec with inspiration. Approximately a 35% or greater increase with inspiration due to greater effects of negative intra-pleural pressure on RA pressure. On contrary RA pressure doesn't change with CP so SVC flow variations are minimal



Cardiomyopathy : Restrictive Versus Constrictive : Respiration Role in Diffrentiatiom

	RCM	CP
Mitral inflow	No respiration variation of mitral inflow E wave velocity, IVRT E/A ratio >2, short DT, diastolic regurgitation	Inspiration: decreased inflow E wave velocity, prolonged IVRT Expiration: opposite changes, short DT, diastolic regurgitation
Pulmonary vein	Blunted S/D ratio (0.5), prominent and prolonged AR No respiration variation, D wave	S/D ratio = 1, Inspiration: decreased pulmonary vein S and D waves Expiration: opposite changes
Tricuspid inflow	Mild respiratory variation of tricuspid inflow E wave velocity, E/A ratio >2, TR peak velocity, no significant respiration change Short DT with inspiration, diastolic regurgitation	Inspiration: increased tricuspid inflow E wave velocity, increased TR peak velocity Expiration: opposite changes Short DT, diastolic regurgitation
Hepatic veins	Blunted S/D ratio, increased inspiratory reversals	Inspiration: minimally increased hepatic veins S and D Expiration: decreased diastolic flow/increased reversals

Thank You