

Patent Foramen Ovale: Pre-procedural Evaluation & Pitfalls of Diagnosis

Jae-Kwan Song, MD, PhD, FACC

Cardiac Imaging Center

Asan Medical Center Heart Institute

University of Ulsan College of Medicine

Seoul, South Korea

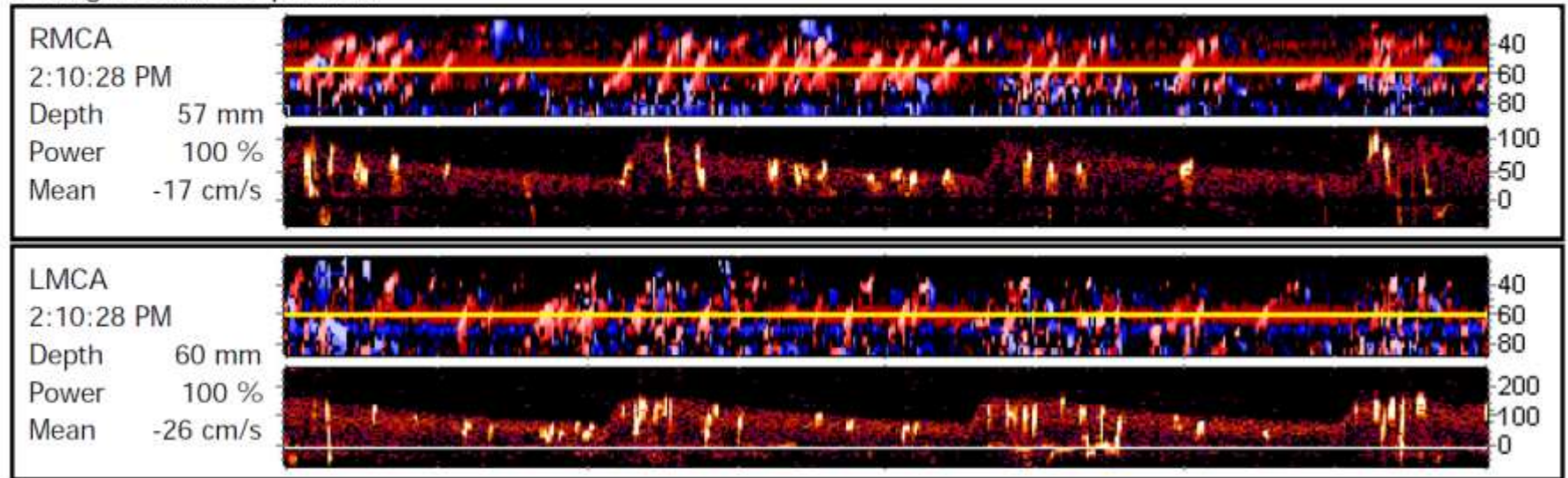
Case Study (1)

- 55/Female, left MCA infarction in Jan 2010

Findings

Embolitic tracks counted during normal respiration: 250.

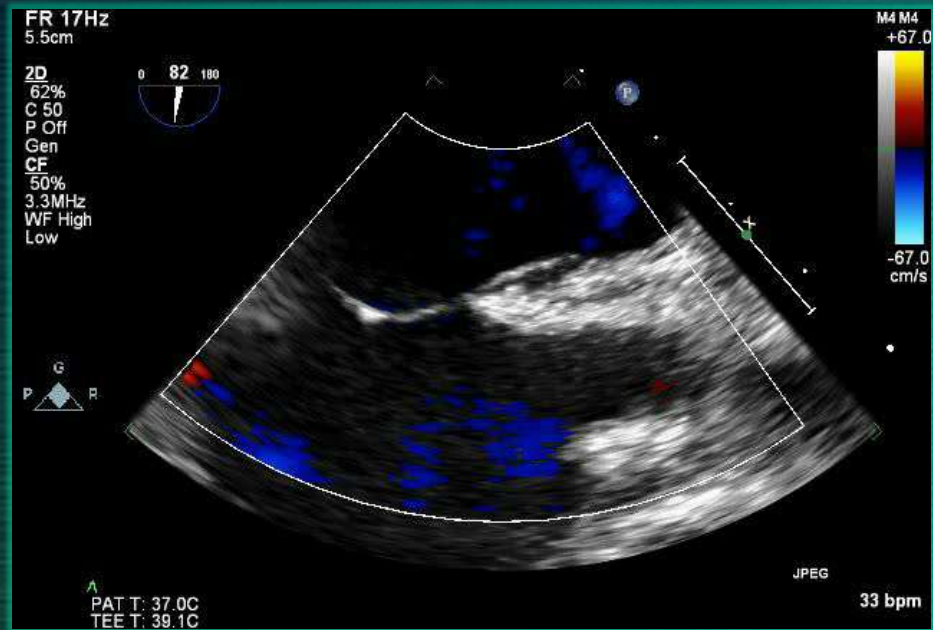
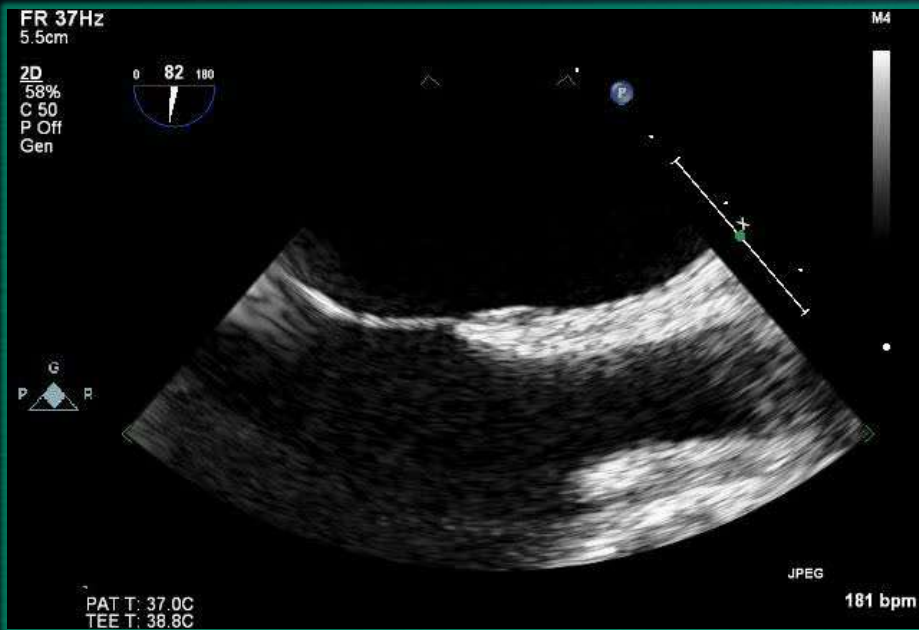
During Normal Respiration



**Transcranial Doppler
HITS (high intensity transient signal)**

Case Study (1)

- 55/Female, left MCA infarction in Jan 2010

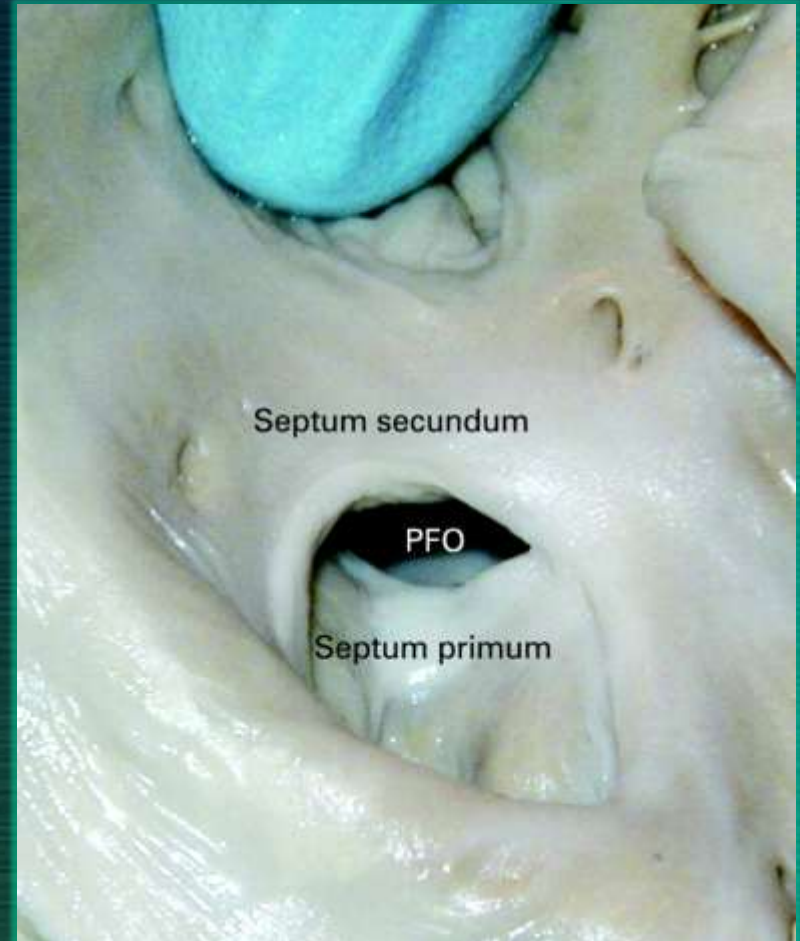
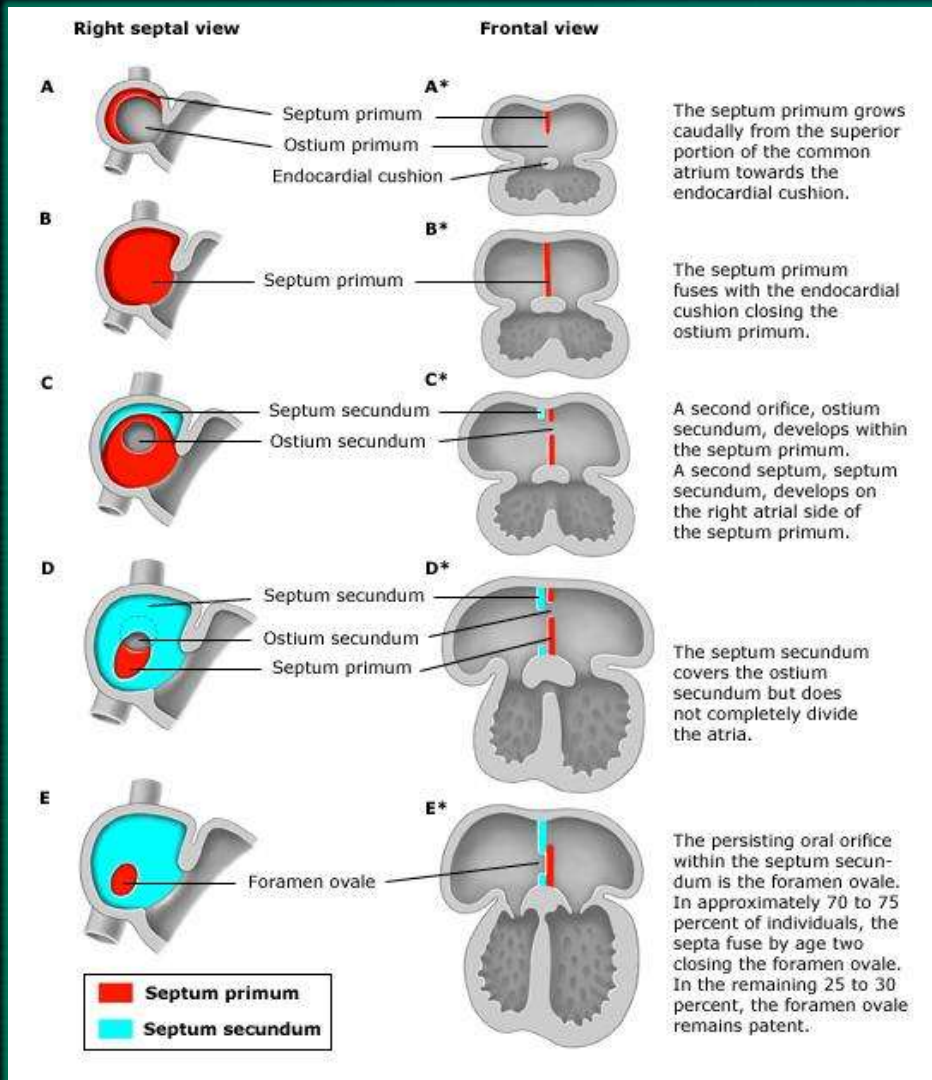


Case Study (1)

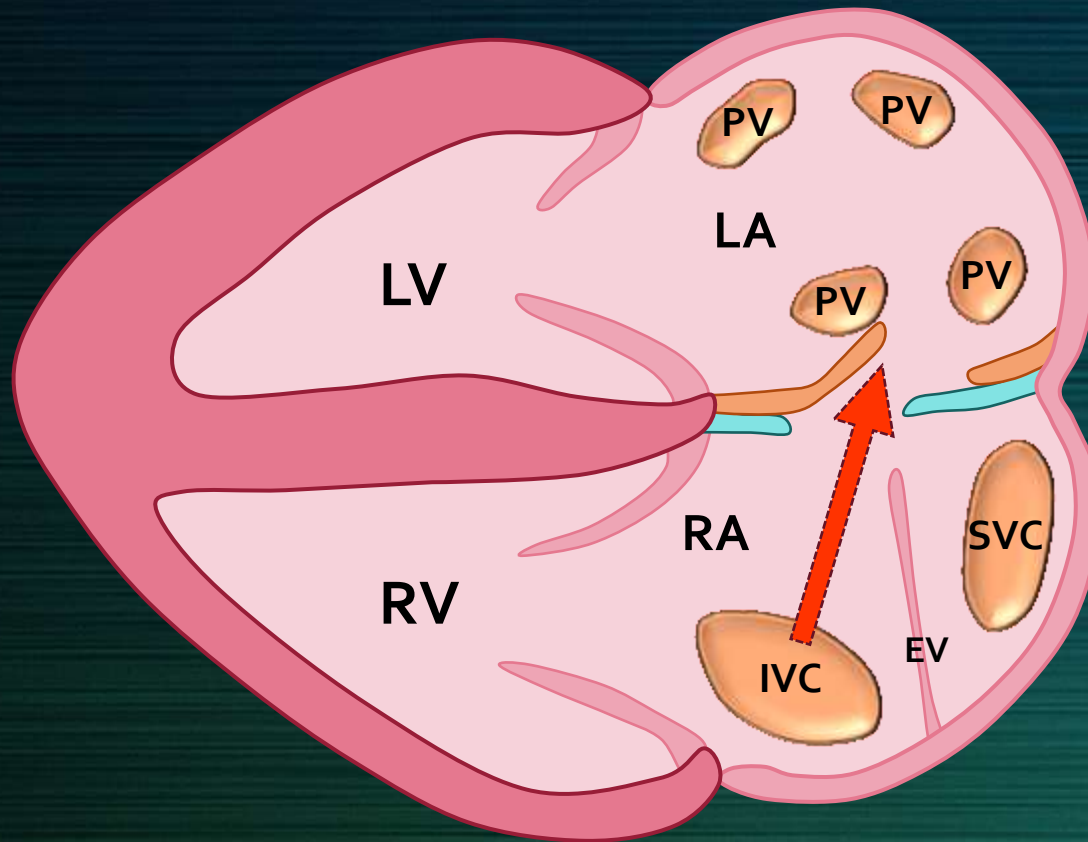


- 1) Normal - observation
- 2) PFO – device closure
- 3) PFO – open heart surgery
- 4) PDA – percutaneous closure
- 5) Needs a further study

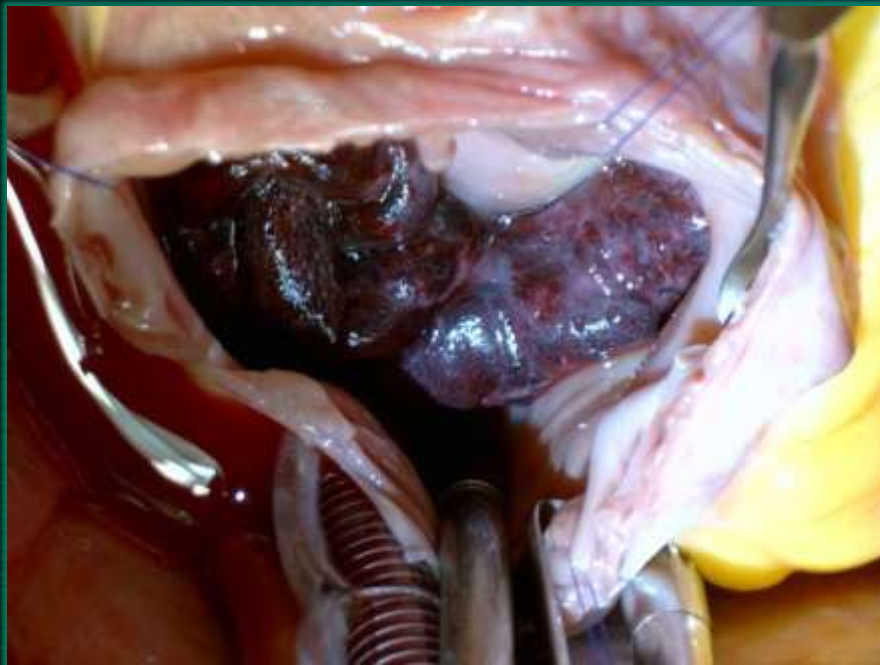
Cardiac Source of Embolism: *Patent Foramen Ovale*



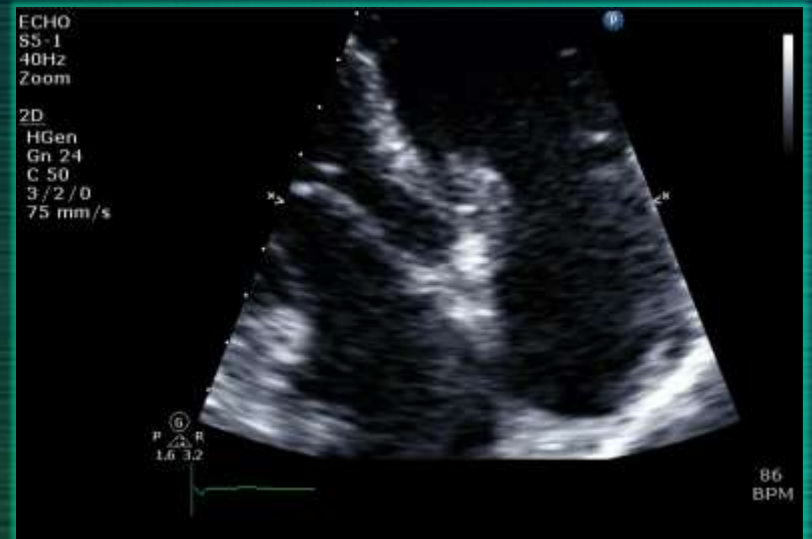
Cardiac Source of Embolism: *Patent Foramen Ovale*



Cardiac Source of Embolism: *Patent Foramen Ovale*

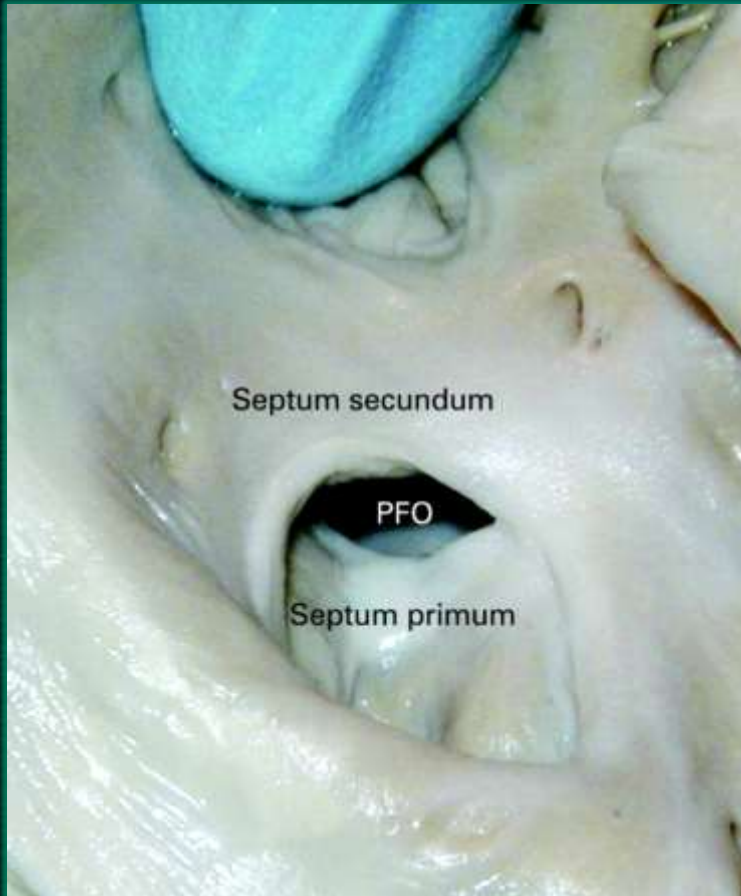


Cardiac Source of Embolism: *Patent Foramen Ovale*



Cardiac Source of Embolism: *Patent Foramen Ovale*

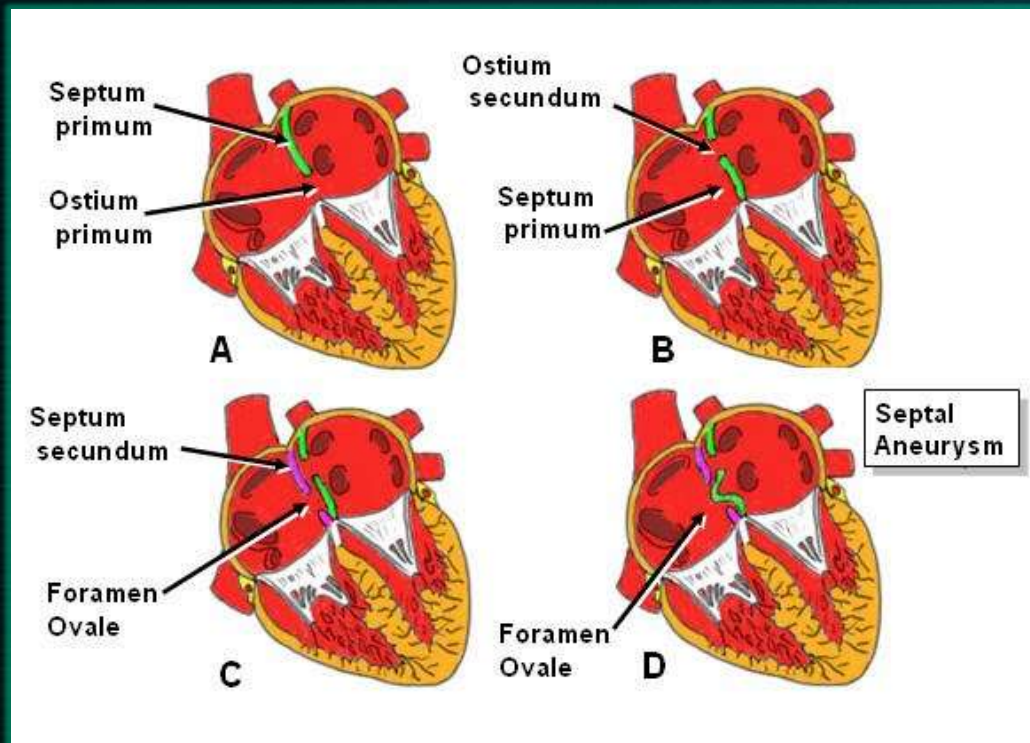
- *Autopsy prevalence of PFO*



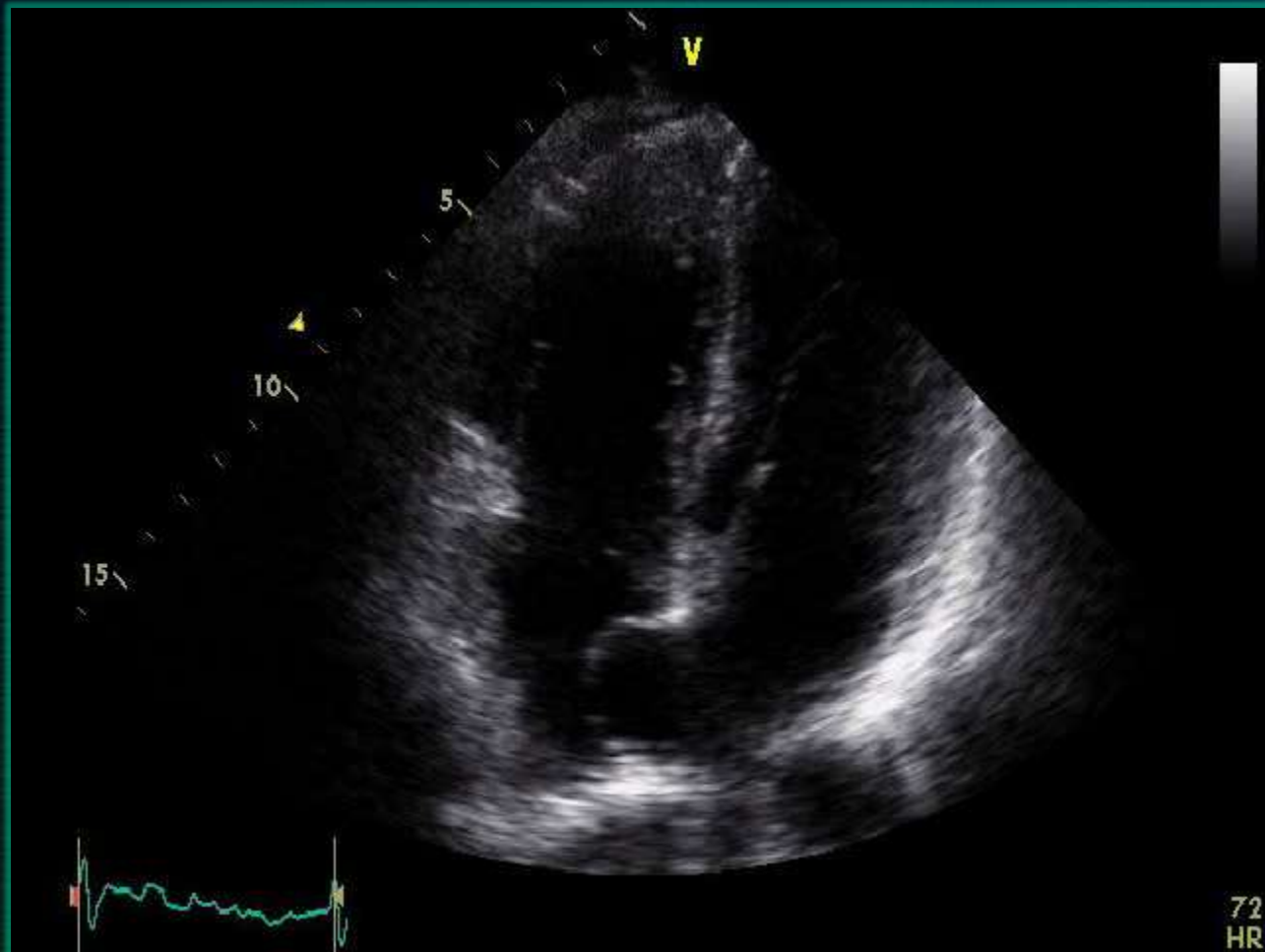
Study	N	Prevalence, %
Parsons and Keith	399	26
Fawcett and Blanchford	306	32
Scammon et al	809	29
Patten	4083	25
Seib	500	17
Wright et al	492	23
Schroeckenstein et al	144	35
Sweeney and Resenquist	64	31
Hagen	965	27
Thompson and Evans	1000	29
Penther	500	15
Total	9262	26

Circulation 2005;112:1063

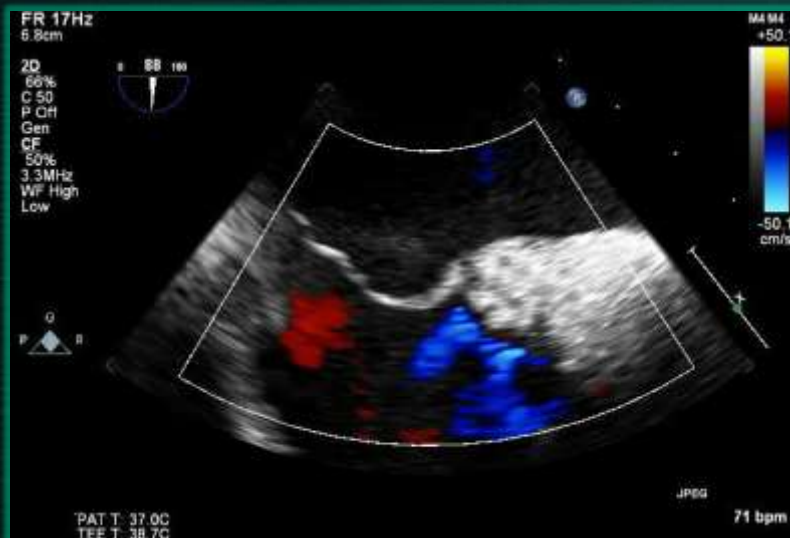
Cardiac Source of Embolism: *Atrial Septal Aneurysm*



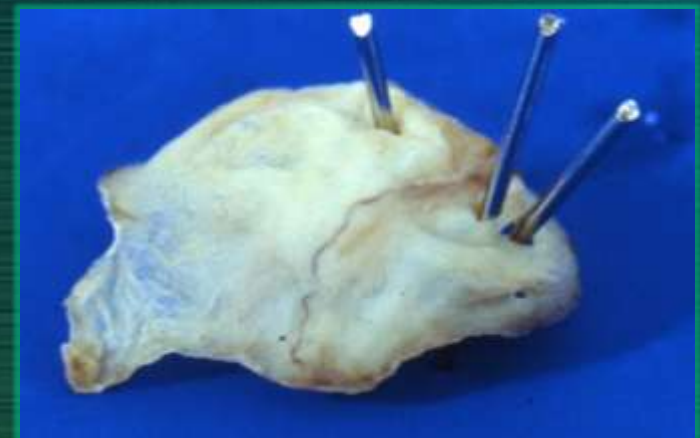
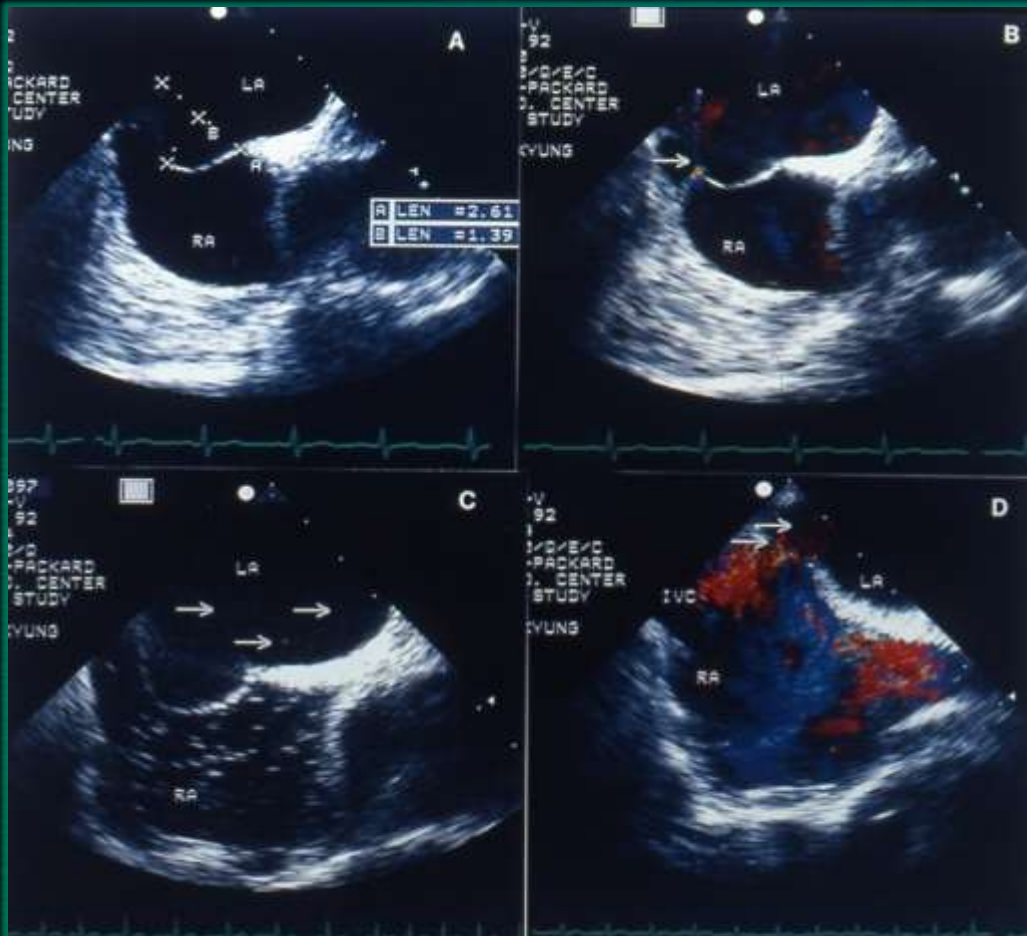
Cardiac Source of Embolism: *Atrial Septal Aneurysm*



Cardiac Source of Embolism: *Atrial Septal Aneurysm*



Cardiac Source of Embolism: *Atrial Septal Aneurysm*



Cardiac Source of Embolism: *Atrial Septal Aneurysm*



Prevalence by TEE: 4.6%

PFO prevalence among patients with ASA

		%
Mügge et al (TEE)	106/195	54
Hanley et al (TEE)	24/49	49
Schneider et al (TEE)	17/22	77
Zabalgoita-Reyes et al (TEE)	17/20	85
Pearson et al (TEE)	20/29	69
Silver et al (autopsy)	8/16	50
Mattioli et al (TEE)	39/44	89
Burger et al (TEE)	18/32	56
Homma et al (TEE)	44/69	64

Total

293/476

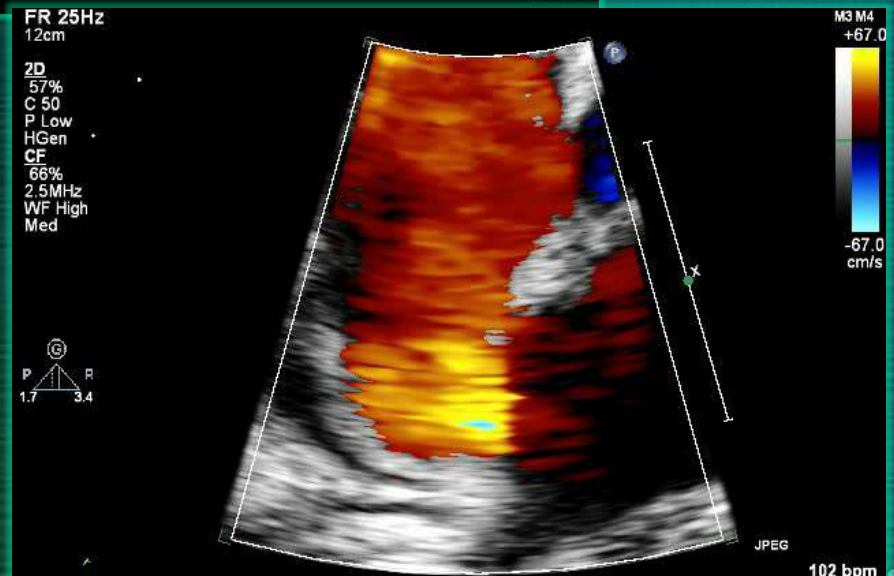
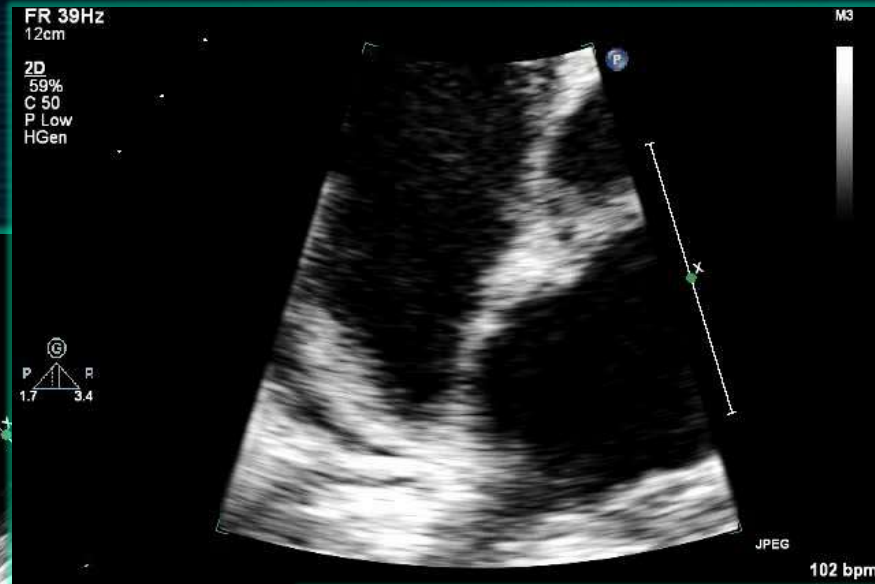
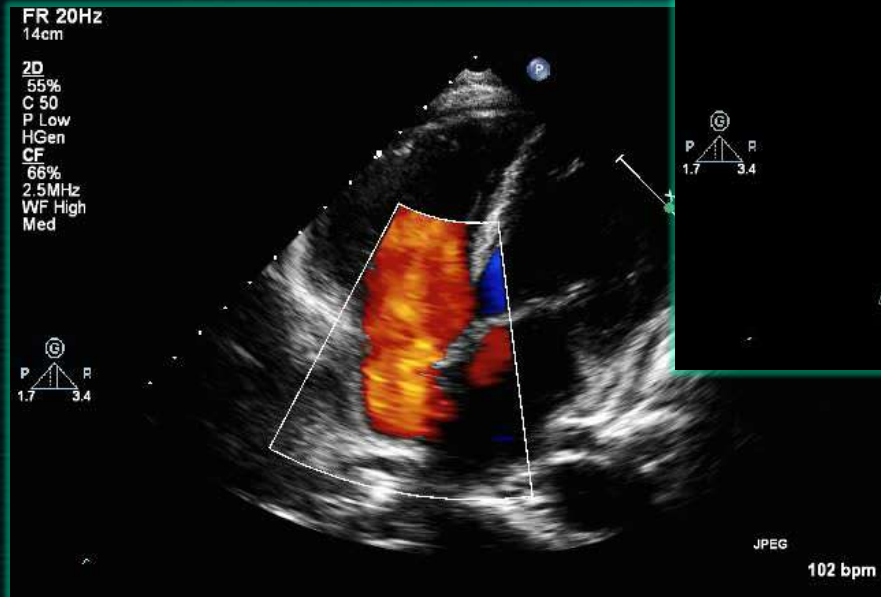
62

Circulation 2005;112:1063

Diagnosis of PFO



Detection of PFO Color Doppler During TTE



Contrast Echocardiography Using Hand-agitated Saline

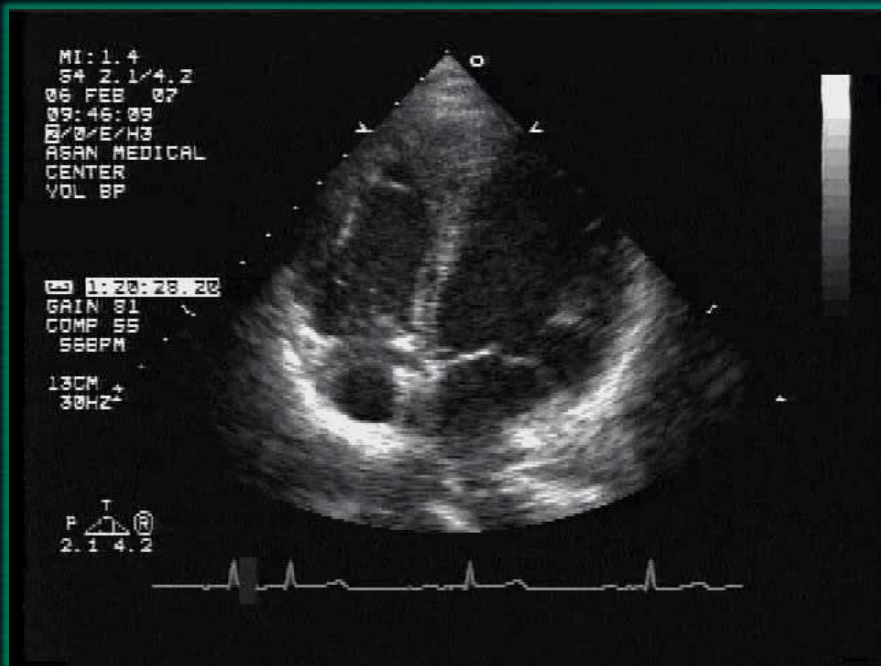


Contrast Echocardiography Using Hand-agitated Saline



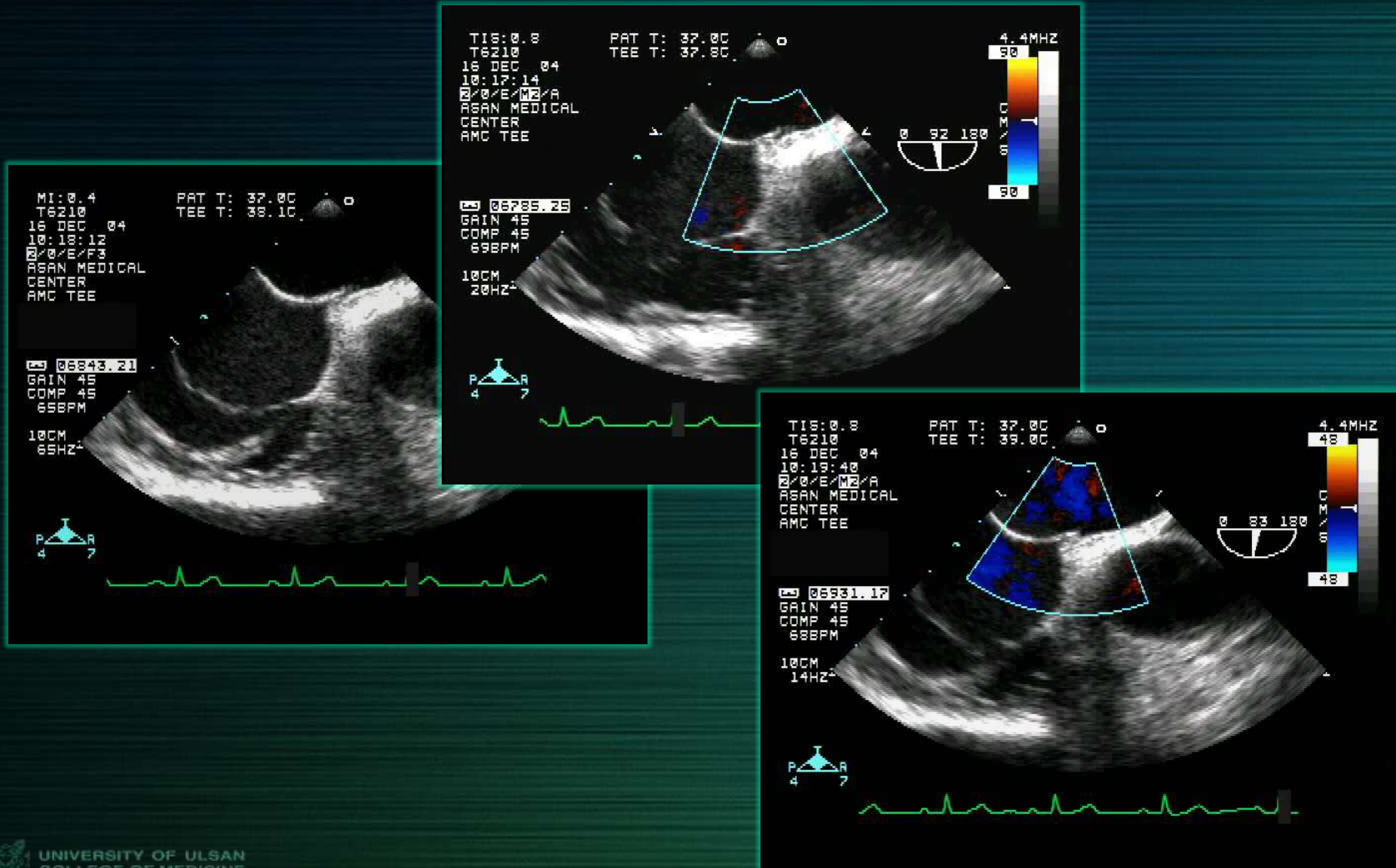
Detection of PFO

Contrast Echocardiography During TTE

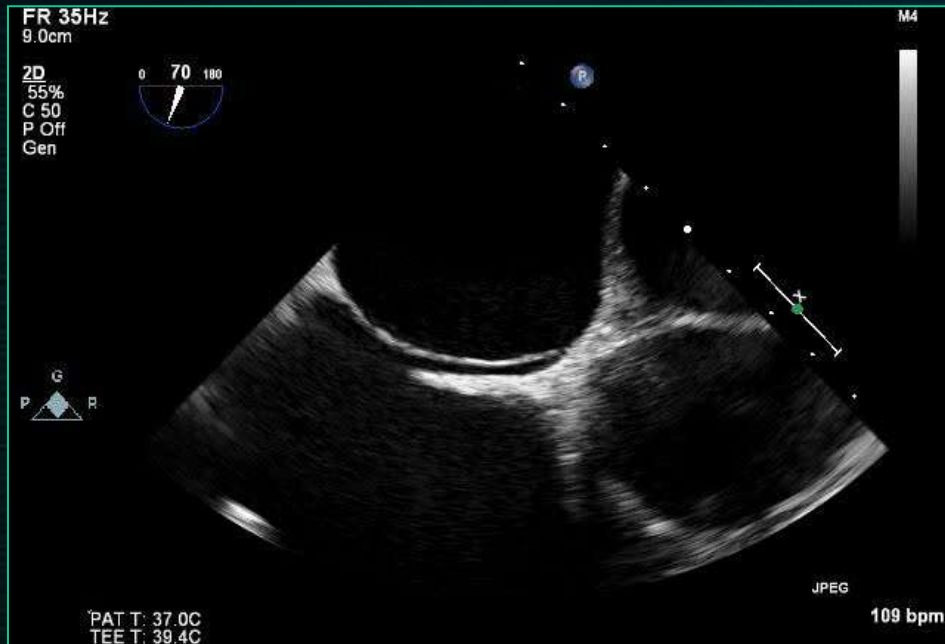


Detection of PFO

Color Doppler During TEE

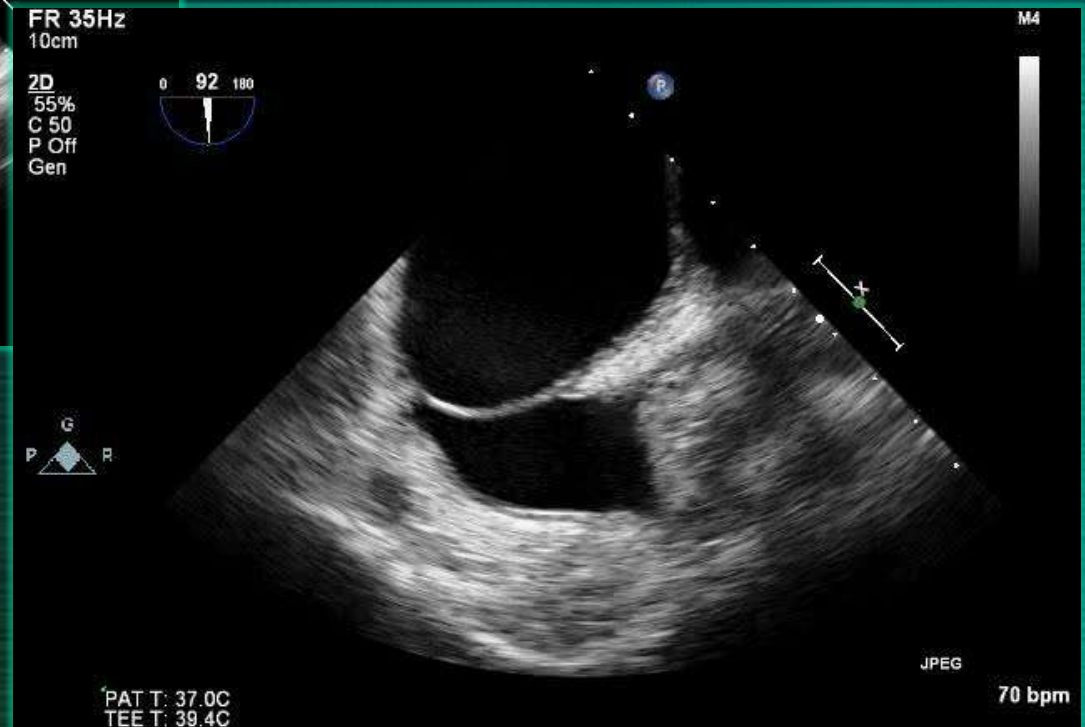
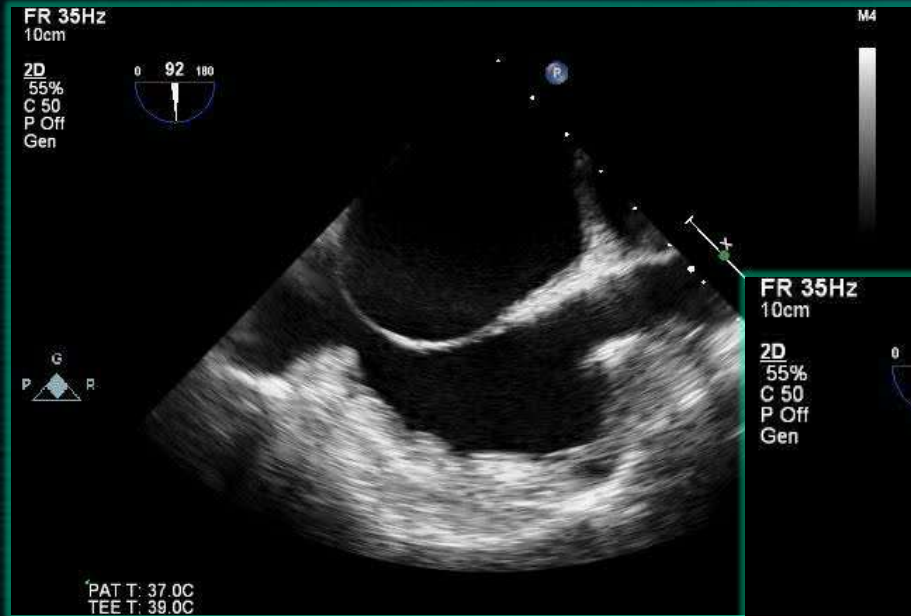


Detection of PFO Color Doppler During TEE



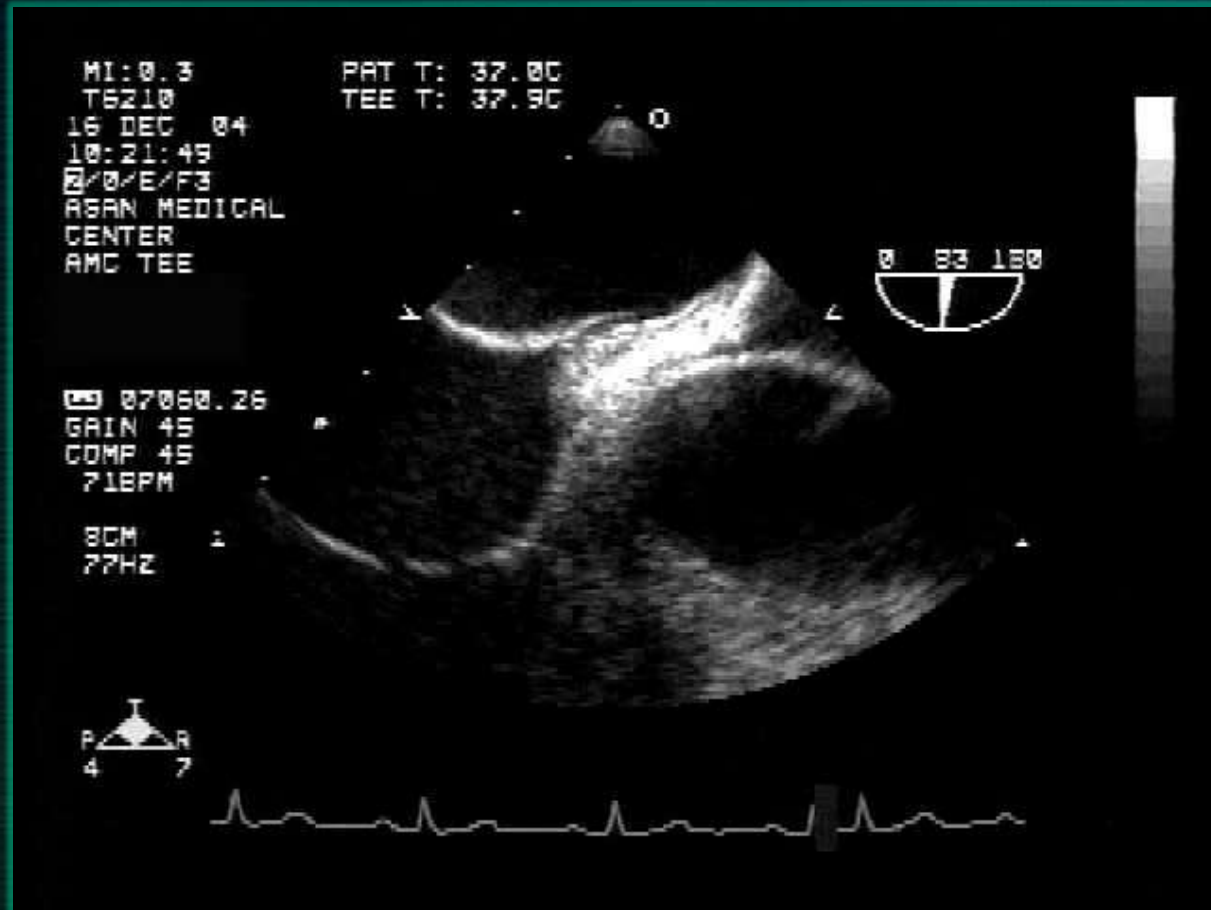
Contrast Echocardiography During TEE

Hand-agitated Saline with Valsava Maneuver



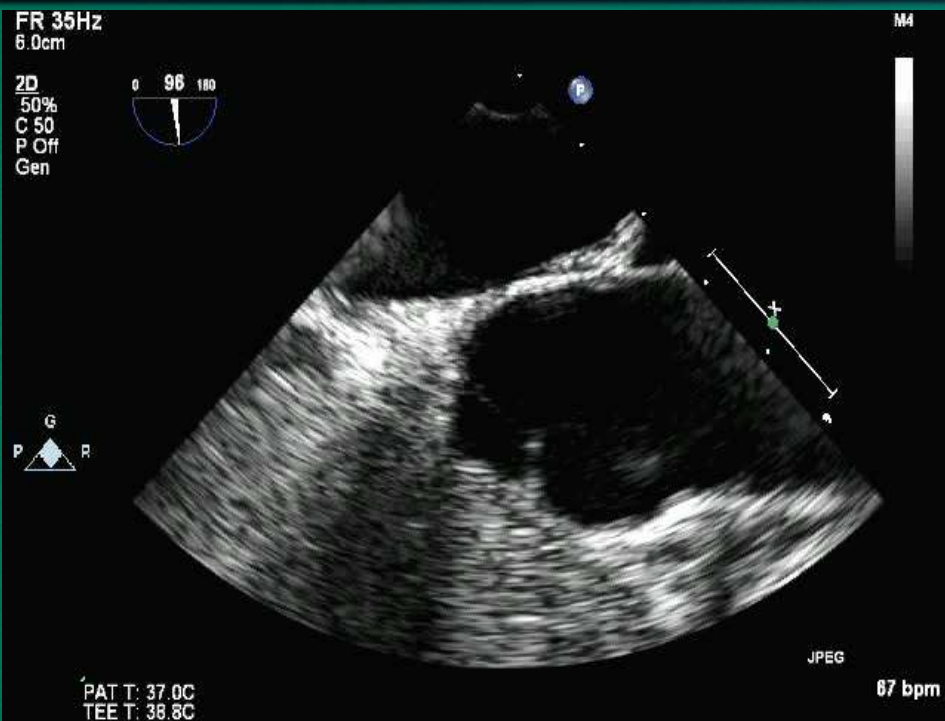
Contrast Echocardiography During TEE

Hand-agitated Saline with Valsava Maneuver

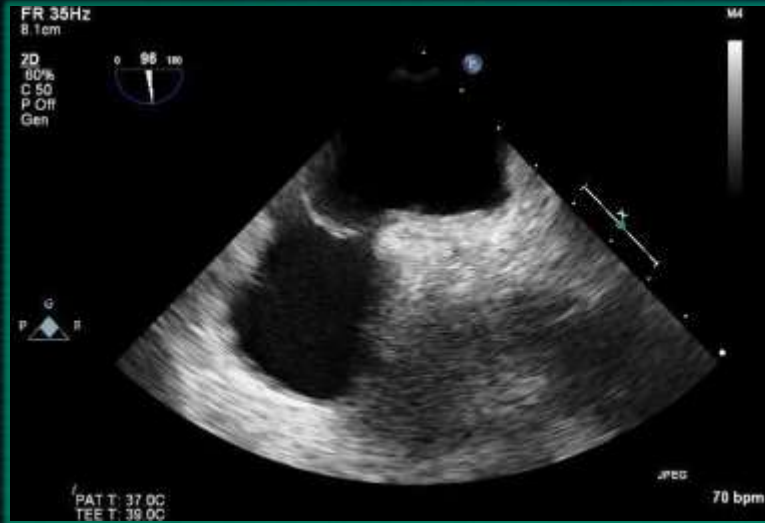


Contrast Echocardiography During TEE

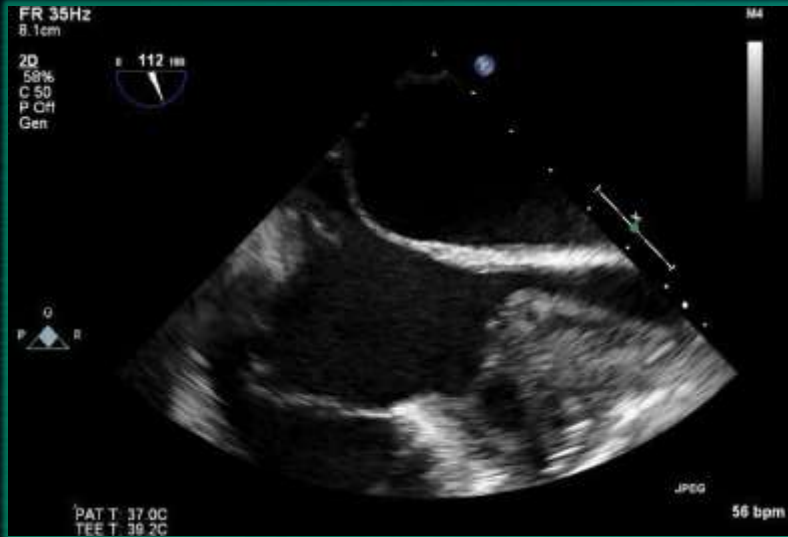
Hand-agitated Saline with Valsava Maneuver



PFO with Many Different Features



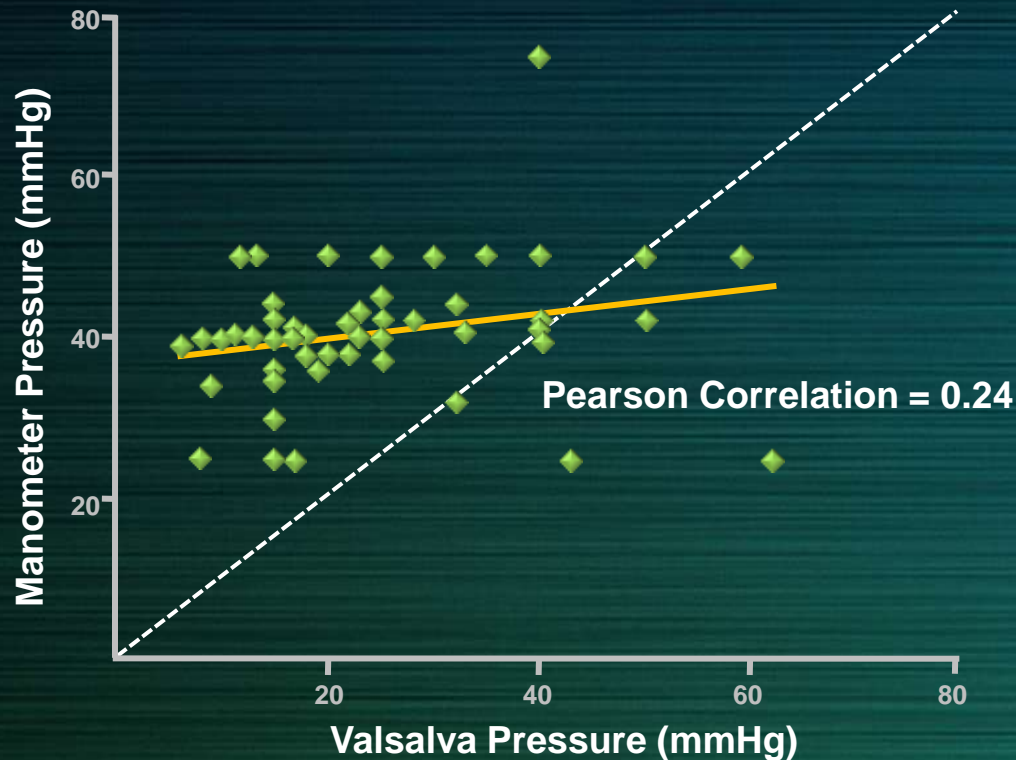
PFO with Many Different Features



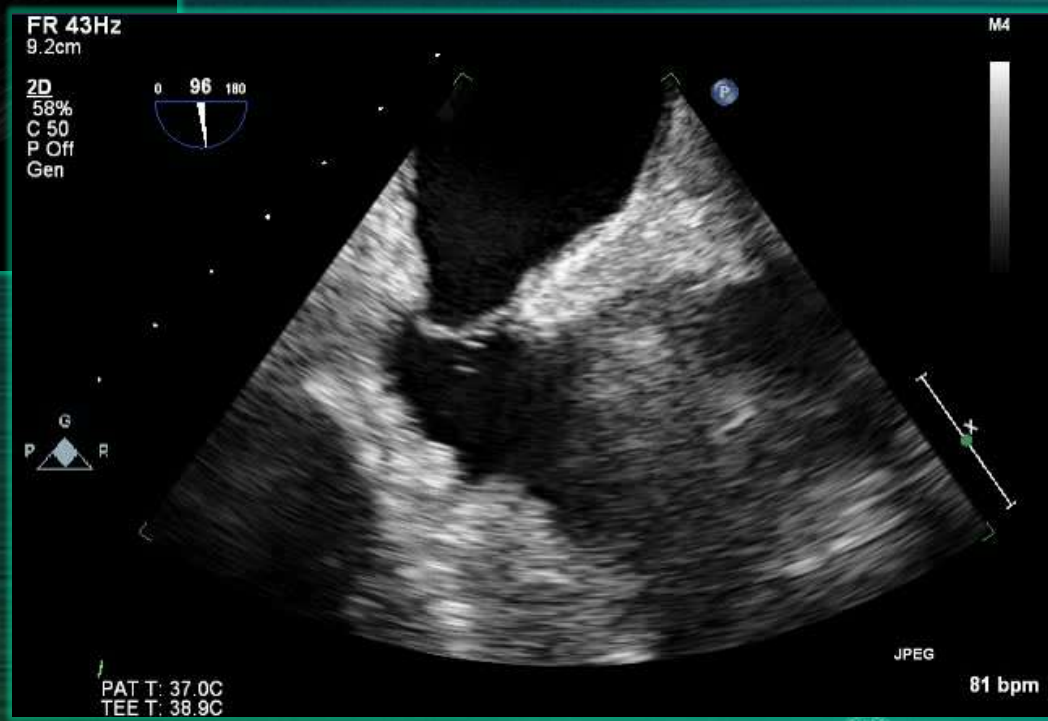
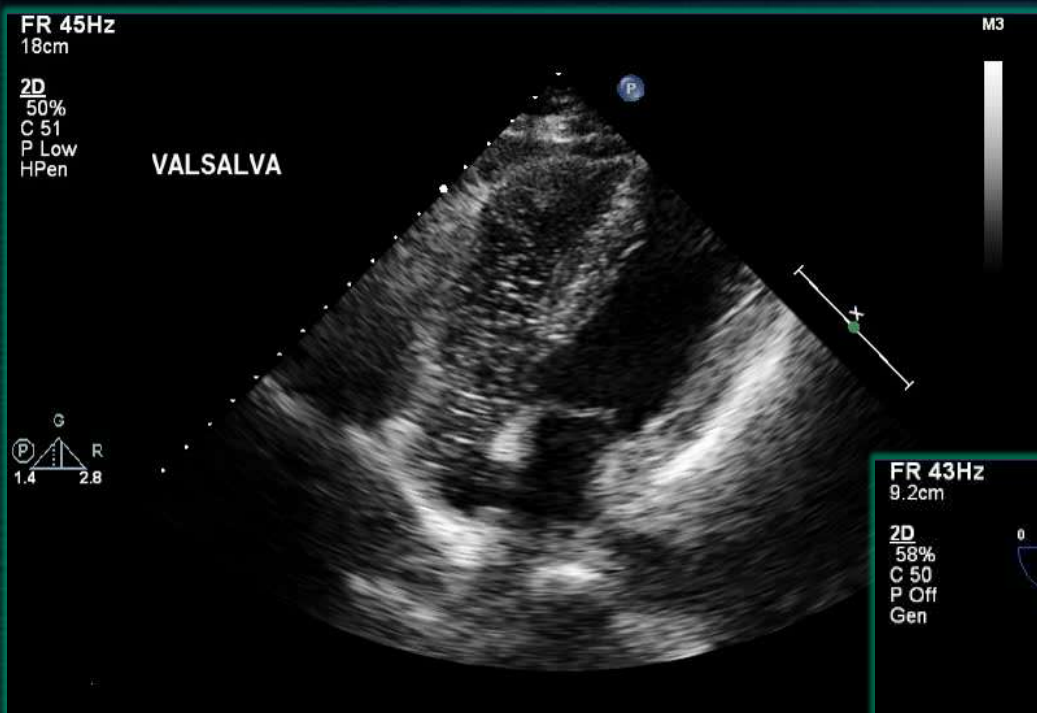
Detection of PFO

Valsalva vs. Manometer

Comparison of right atrial pressure measured during Valsalva maneuver vs. Manometer



TTE vs. TEE: Why TEE?



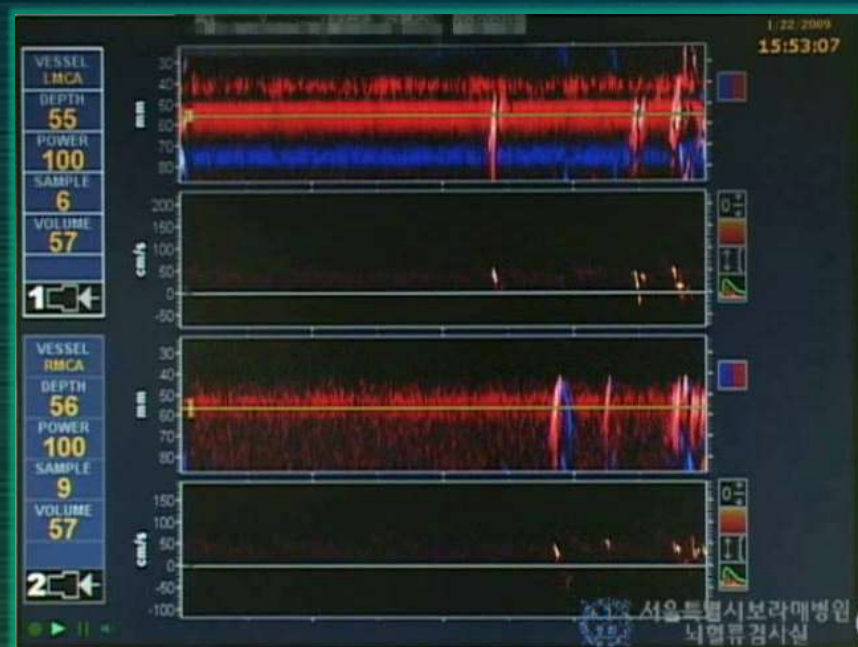
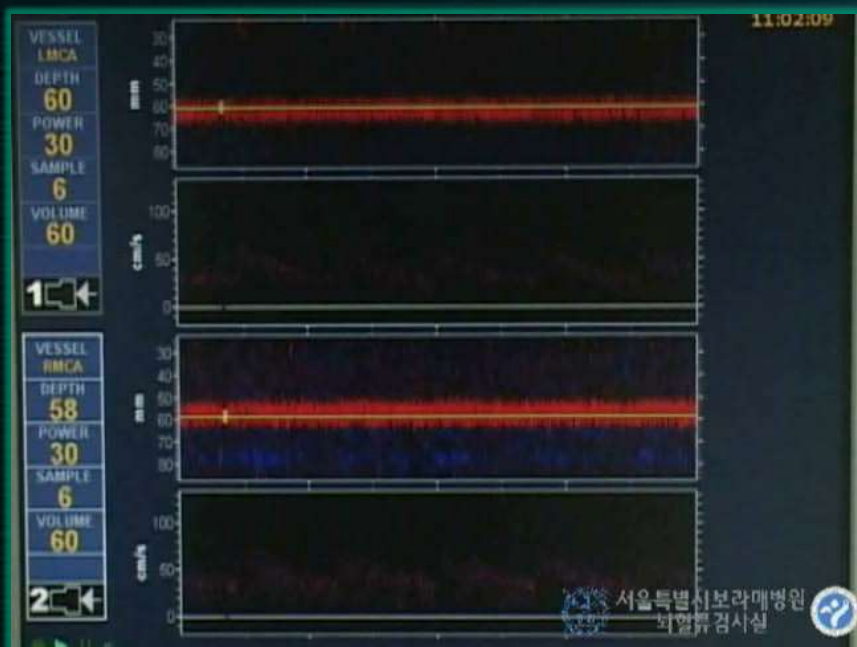
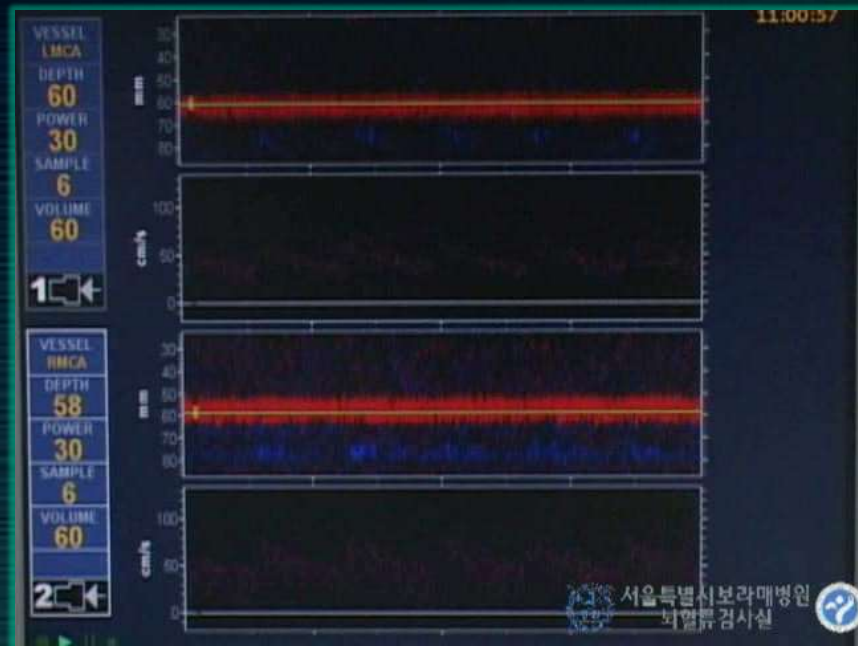
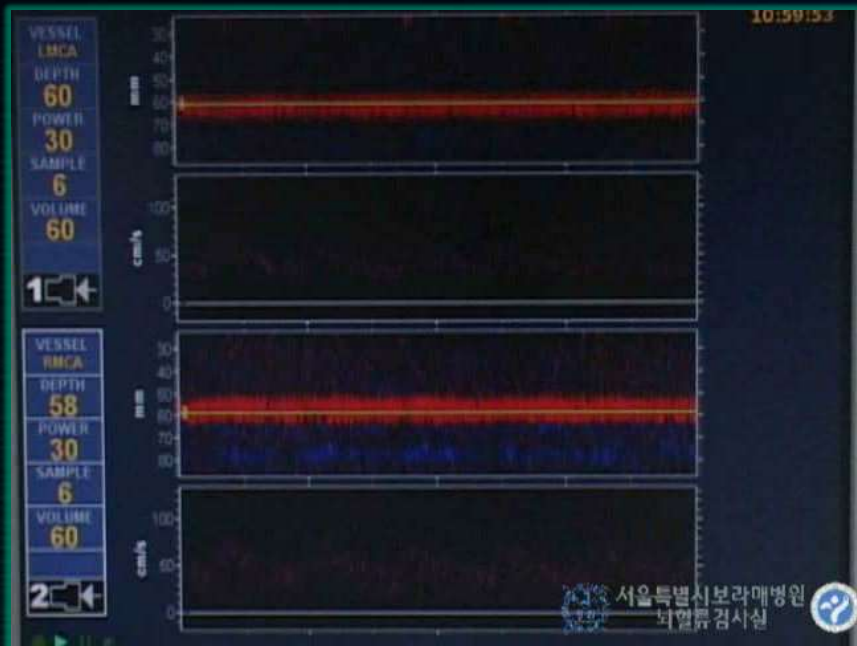
Detection of PFO: Why TEE?

Transcranial Doppler

- Detection of *microbubble in the cerebral circulation*
- Does not necessarily imply the presence of PFO
- TCD *cannot identify the site of R-L shunt*

Study	Patients, n	TTE, % (n/total)	TCD, % (n/total)	TEE, % (n/total)
Teague and Sharma	46	26 (12/46)	41 (19/46)	...
Di Tullio et al	80	18 (14/80)	26 (21/80)	...
Jauss et al	50	...	28 (14/50)	30 (15/50)
Karnik et al	36	...	36 (13/36)	42 (15/36)
Job et al	137	...	42 (58/137)	47 (65/137)
Klötzsch et al	111	...	38 (42/111)	41 (46/111)
Nemec et al	32	23 (7/32)	41 (13/32)	41 (13/32)
Di Tullio et al	49	18 (9/49)	27 (13/49)	38 (19/49)
Total		20 (42/207)	36 (193/541)	42 (173/415)

Circulation 2005;112:1063



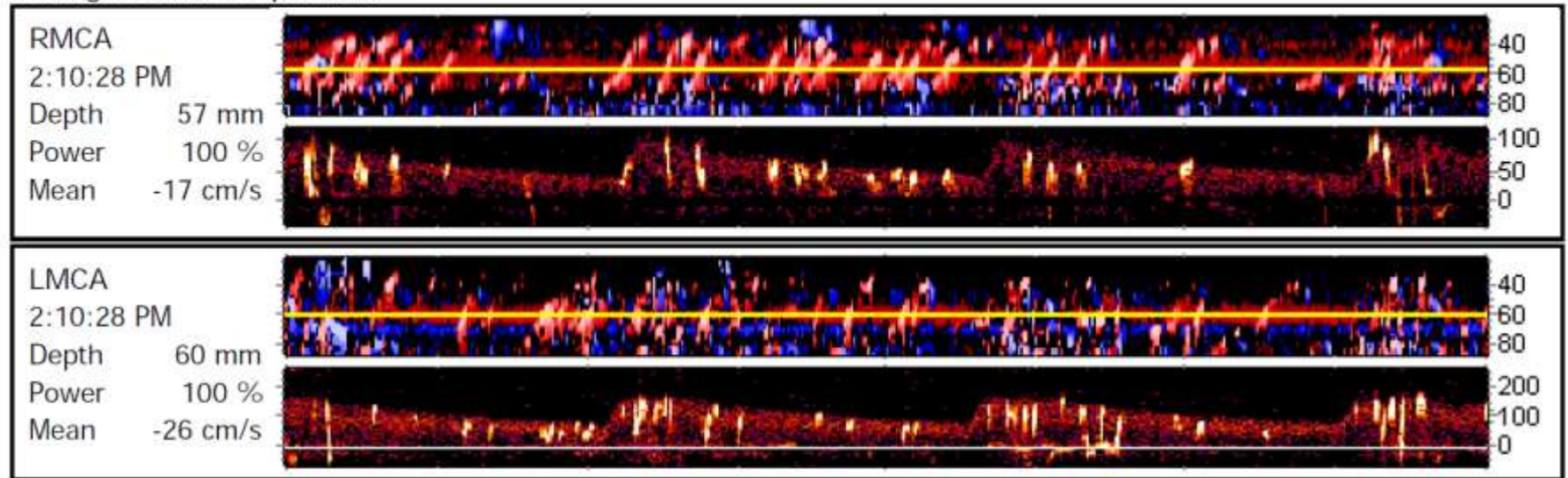
Case Study (1)

- 55/Female, left MCA infarction in Jan 2010

Findings

Embolitic tracks counted during normal respiration: 250.

During Normal Respiration



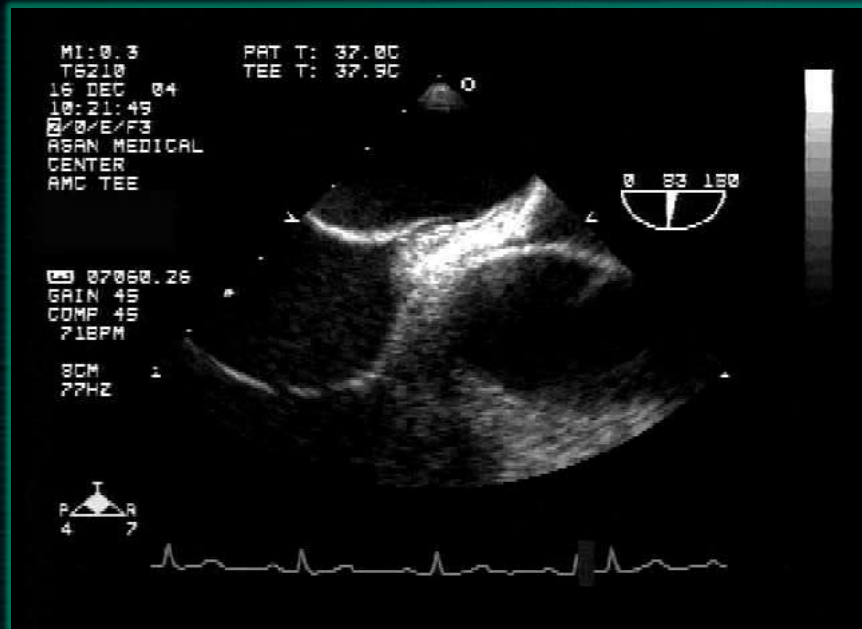
Transcranial Doppler
HITS (high intensity transient signal)

Case Study (1)



- 1) Normal - observation
- 2) PFO – device closure
- 3) PFO – open heart surgery
- 4) PDA – percutaneous closure
- 5) Needs a further study

Case Study (1)

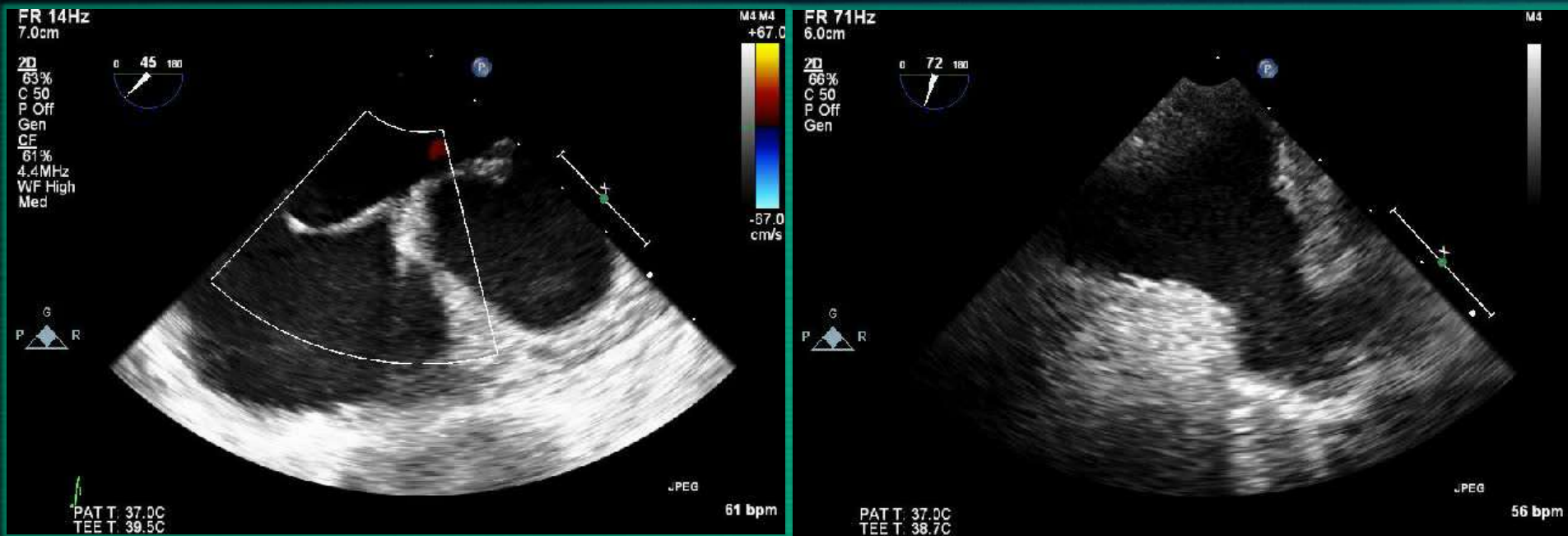


PFO

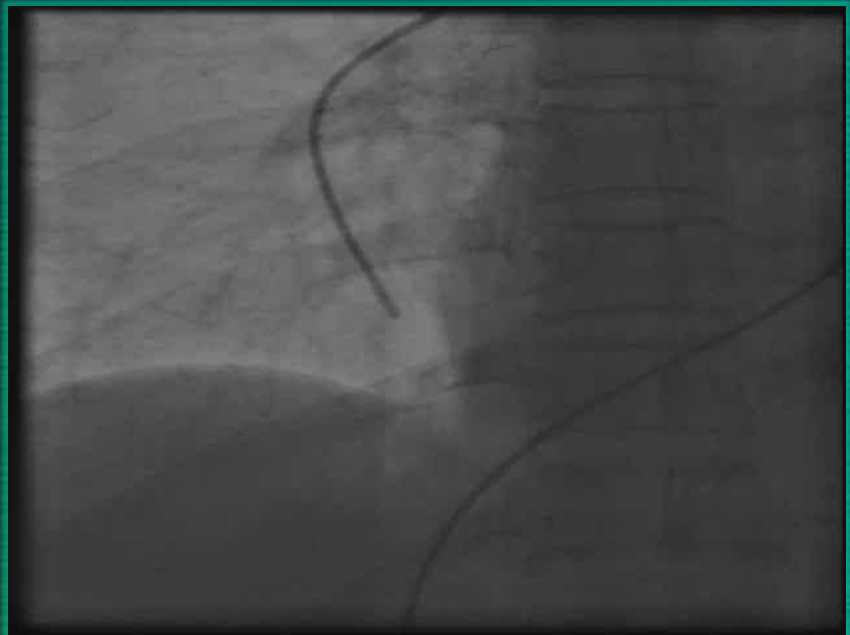
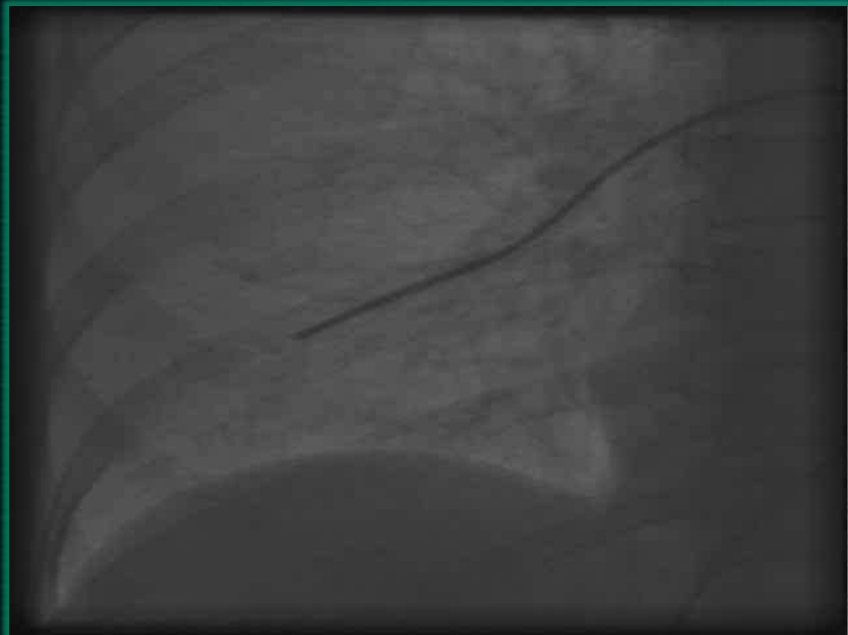
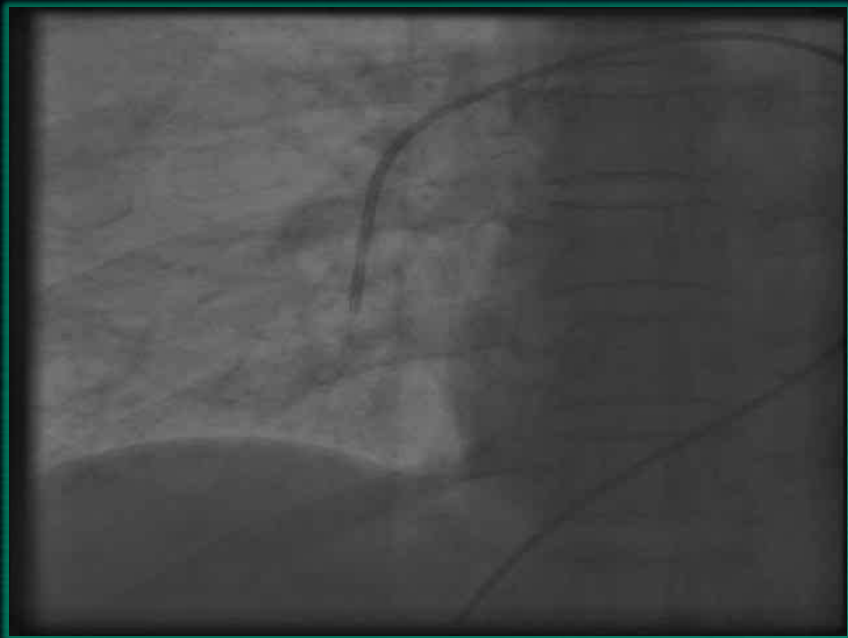


Case F/55

Case Study (1)

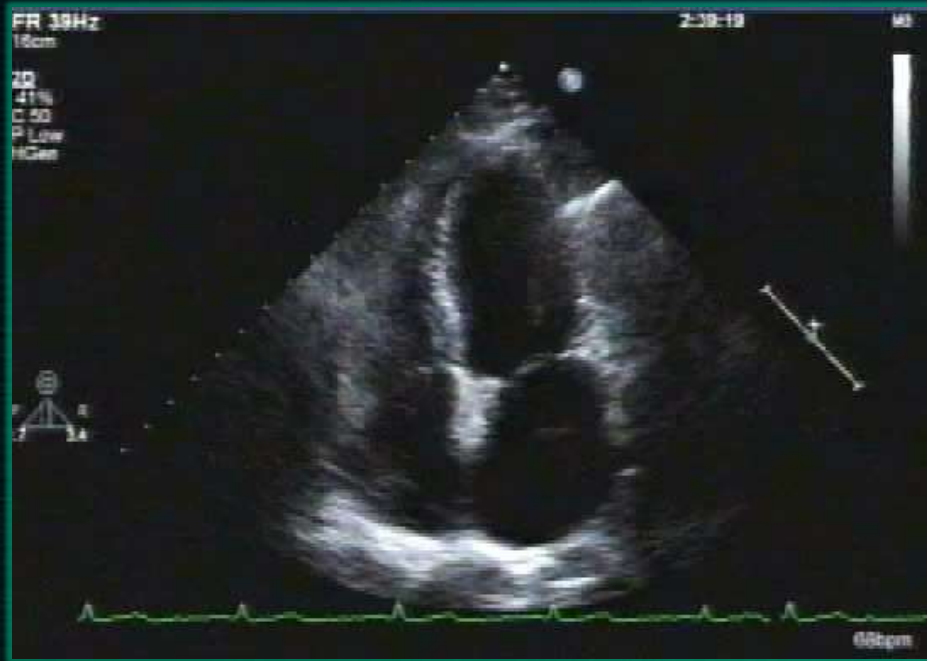


s/o Pulmonary AV fistula

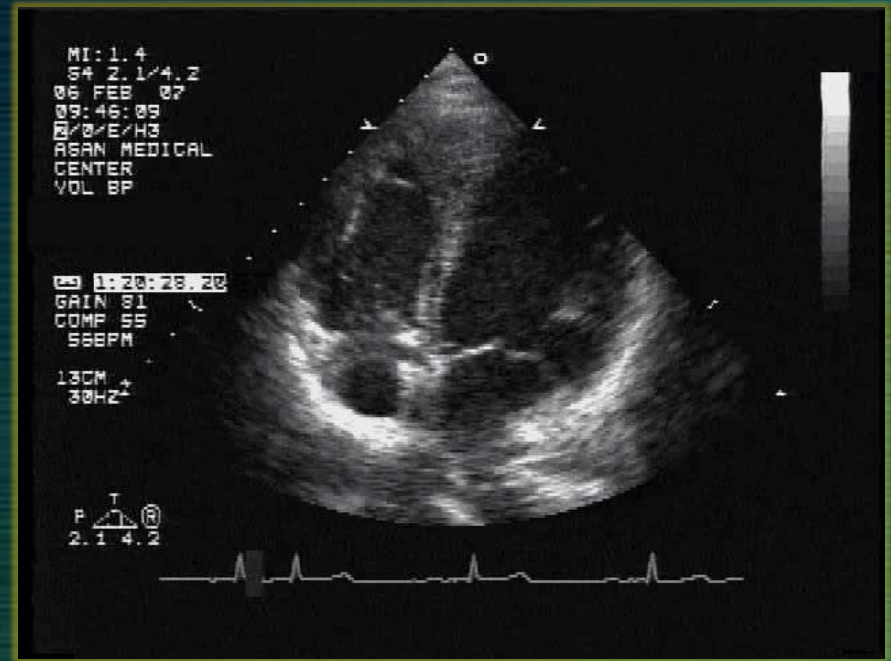




Pulmonary AV Malformation vs. PFO

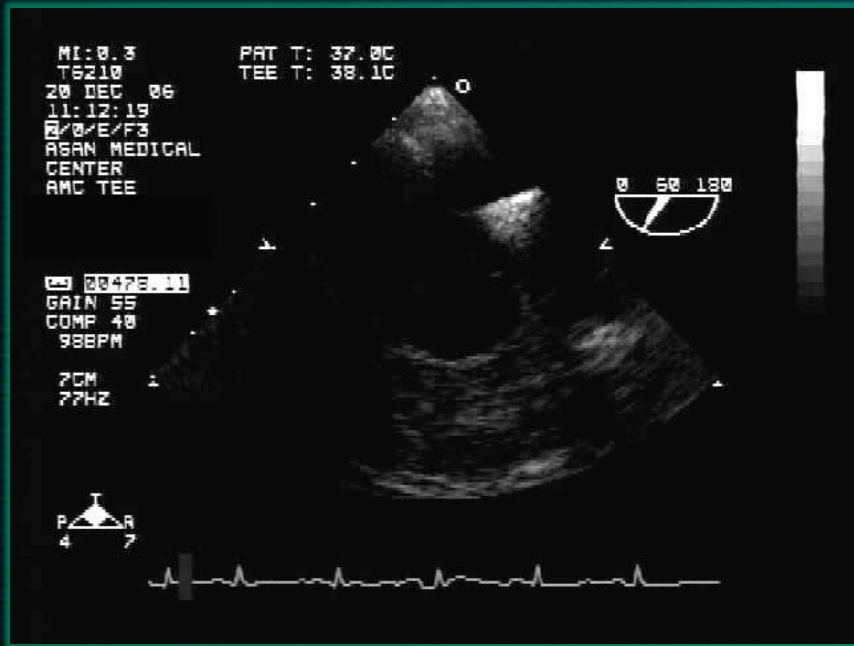


Pulmonary AV Malformation

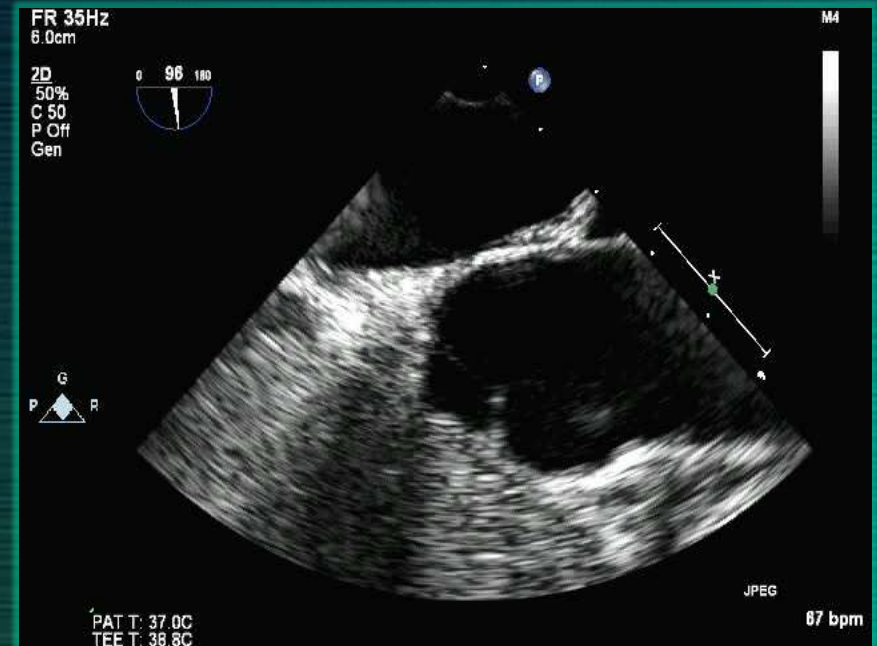


PFO

Pulmonary AV Malformation vs. PFO

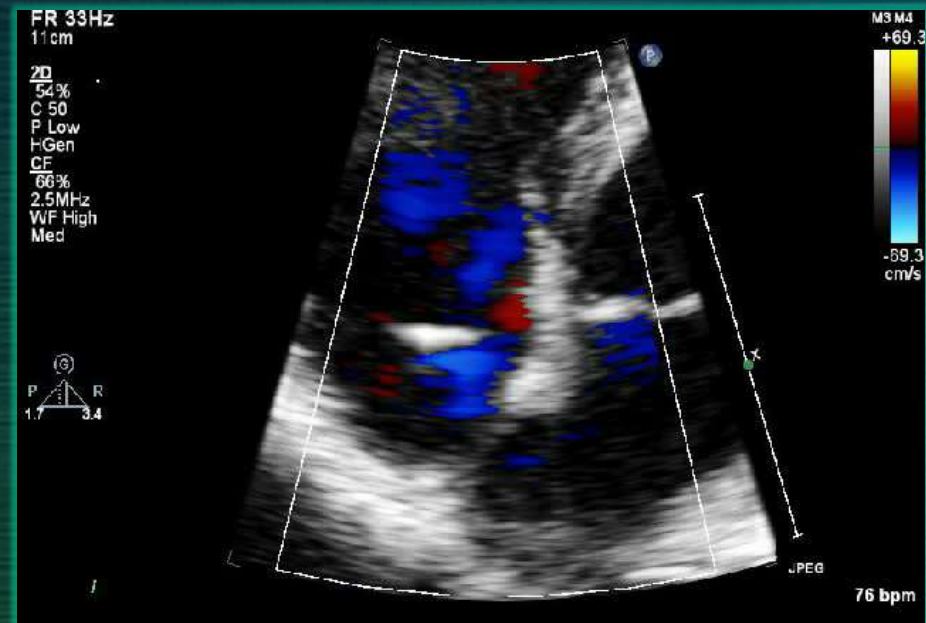


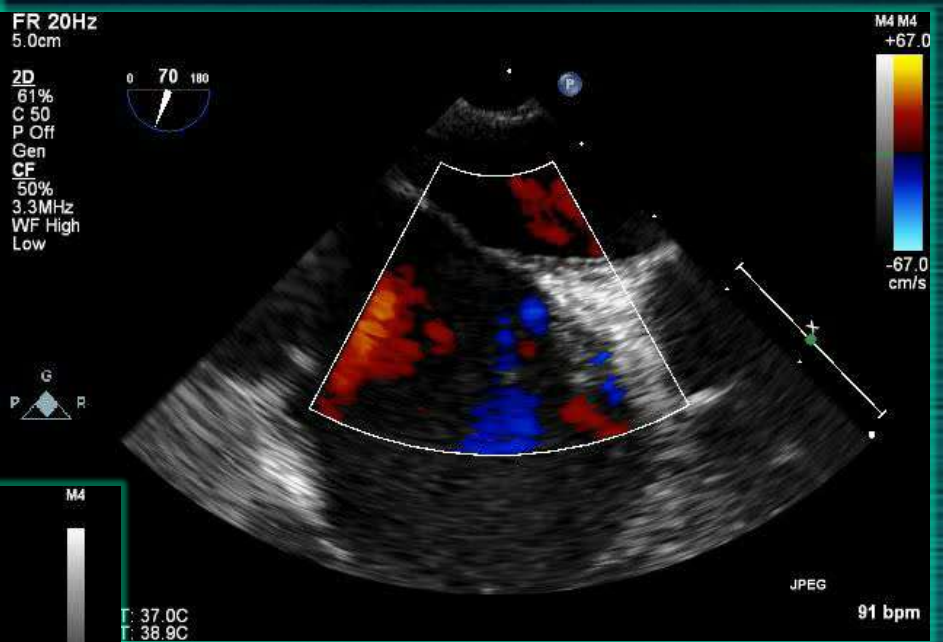
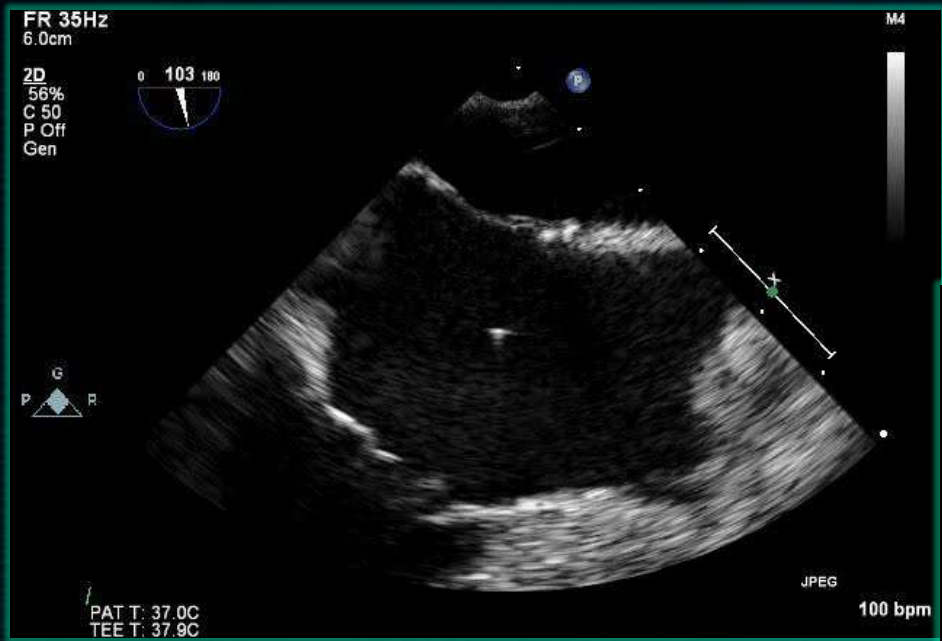
Pulmonary AV Malformation



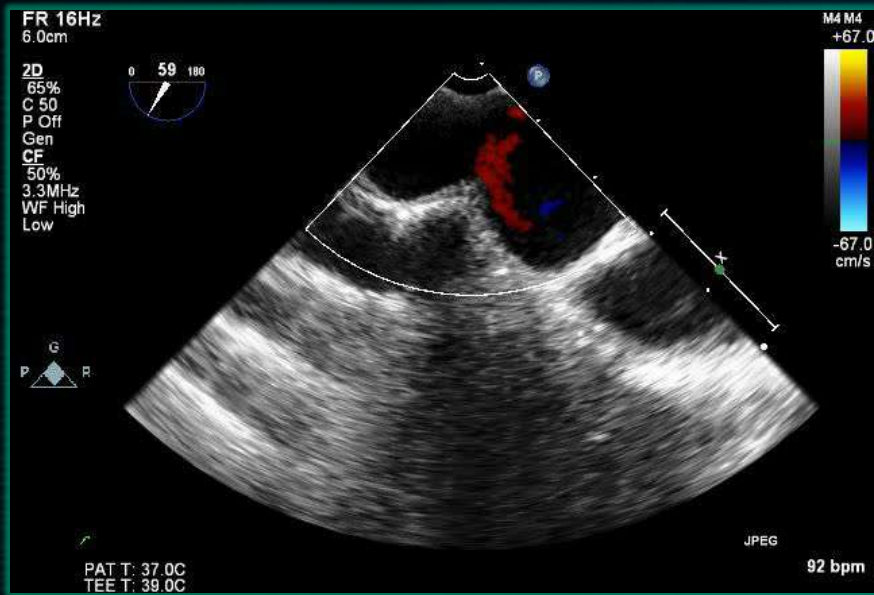
PFO

- F/38
- Sudden syncope - left PICA infarction on MRI
- PFO on TEE
- PFO direct closure through right thoracotomy
- On Clopidogrel
- Sudden left leg weakness and dizziness one year later

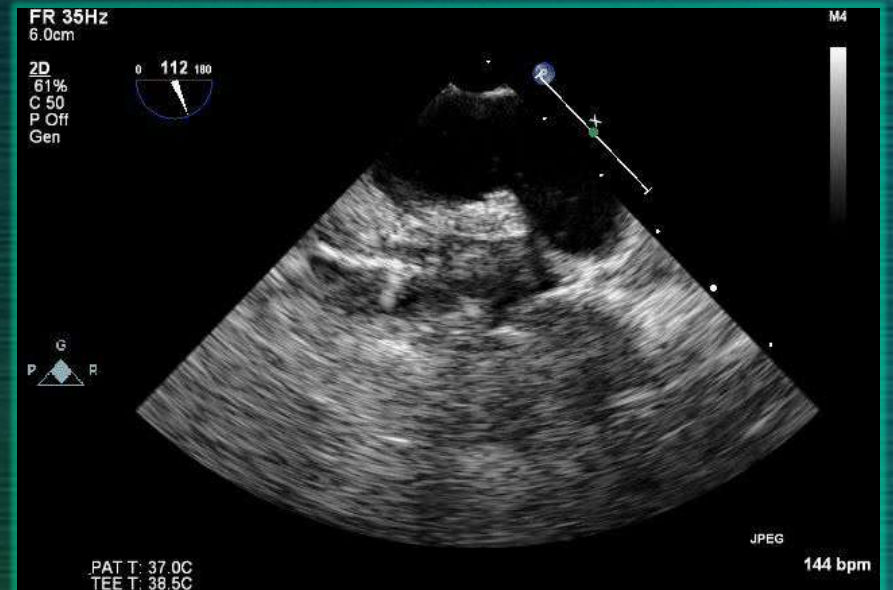
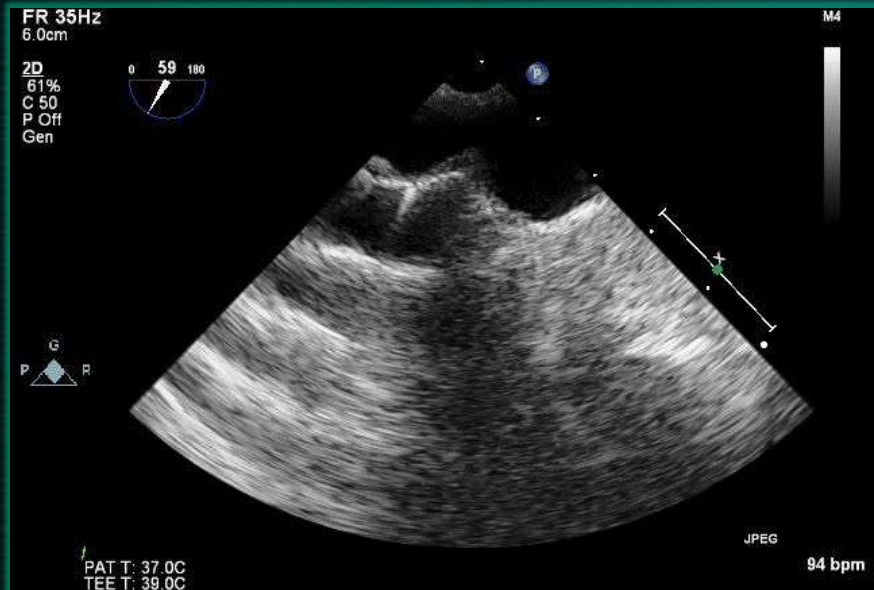
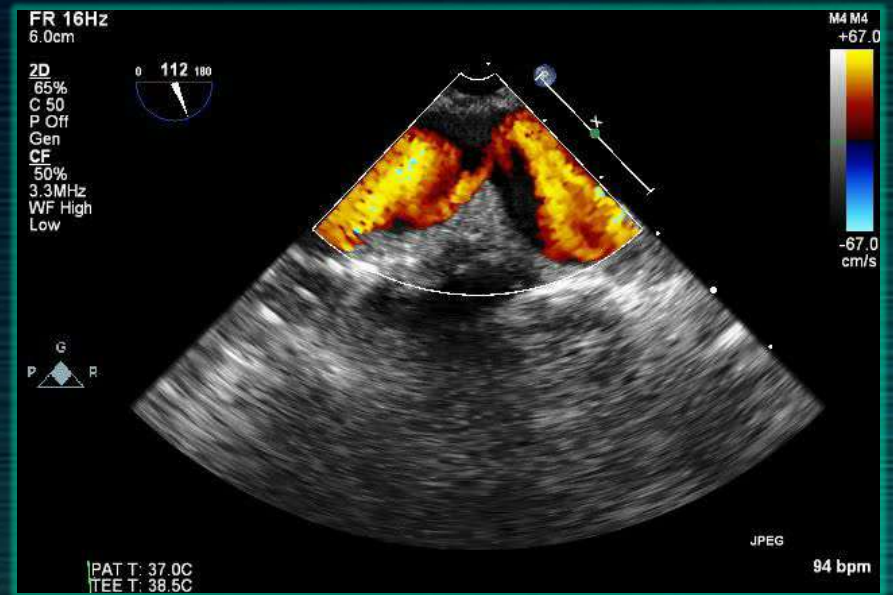


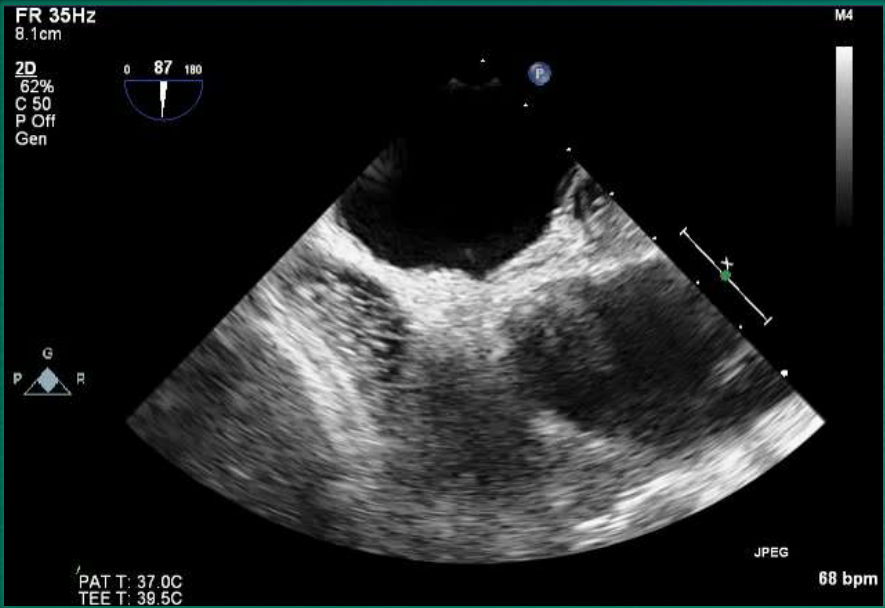


Right Pulmonary Vein

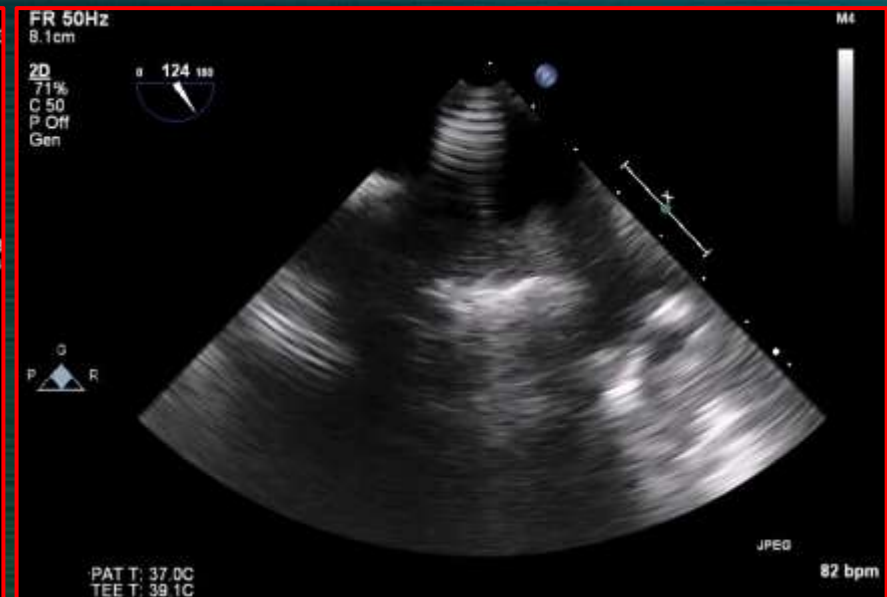
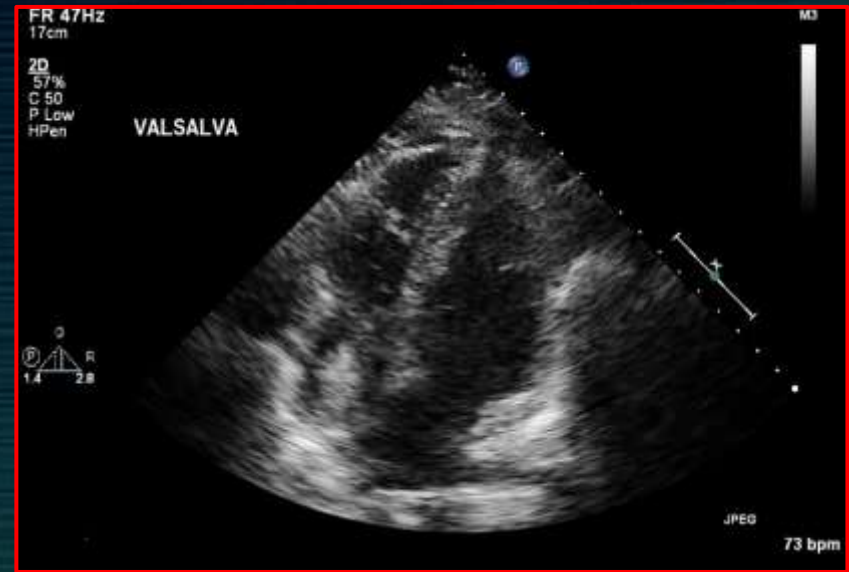
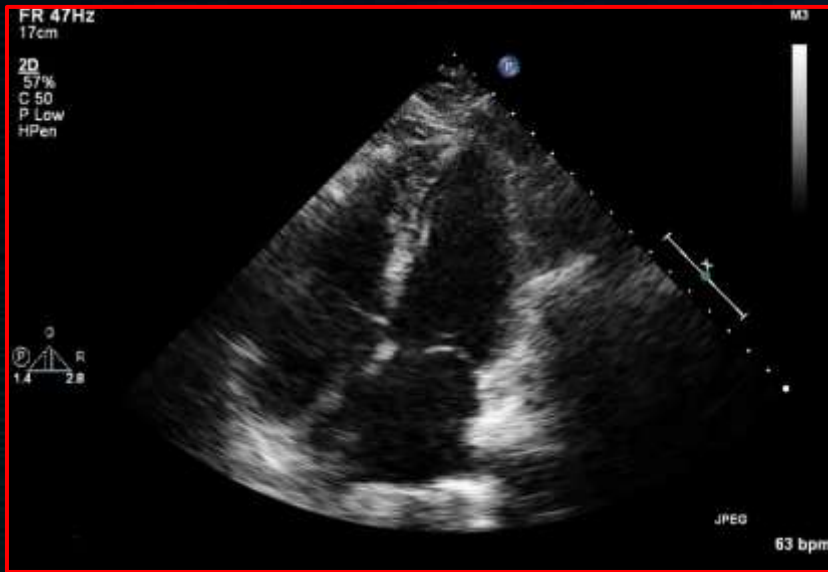


Left Pulmonary Vein

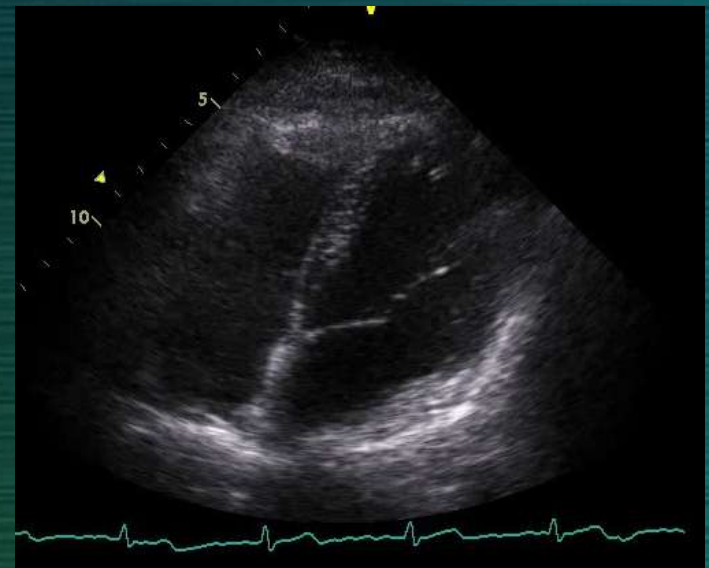
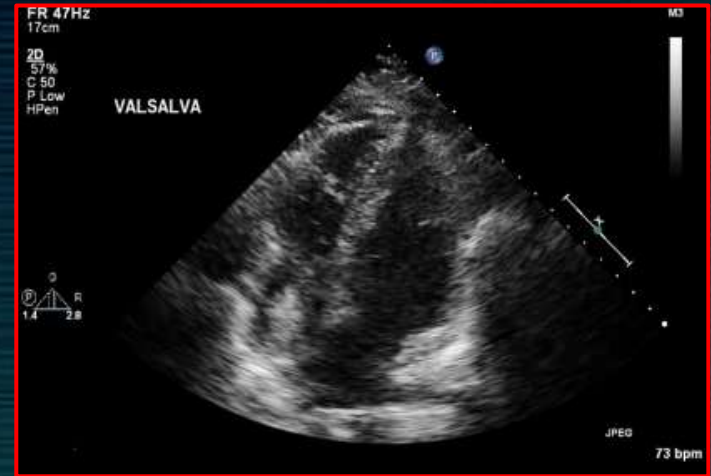




- 48/female, history of cryptogenic stroke with PFO

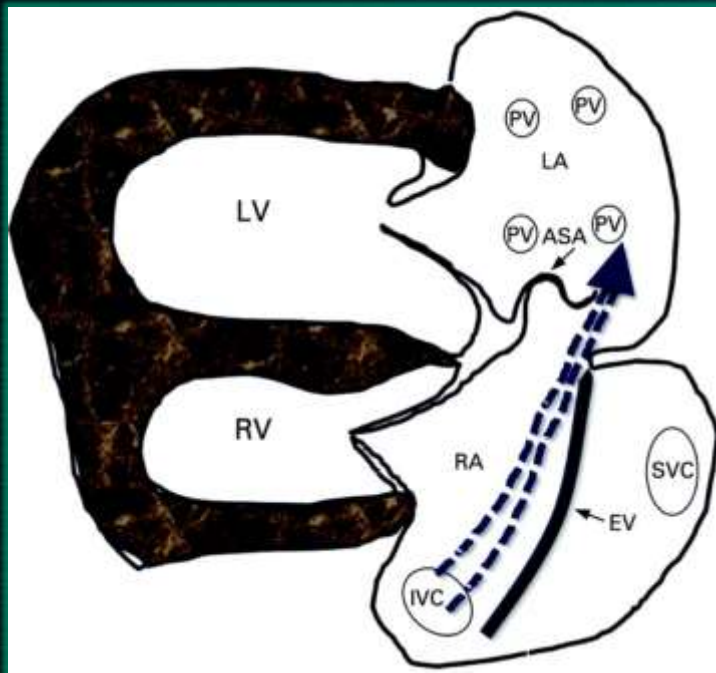


- 48/female, history of cryptogenic stroke with PFO



Detection of PFO

Upper vs. Lower Extremity Injection



Neurology 1998;50:1423

Femoral Vein Delivery of Contrast Medium
Enhances Transthoracic Echocardiographic
Detection of Patent Foramen Ovale

(JACC 1993;22:1994)

33% (23/70) vs. 13% (9/70), $p < 0.001$

Femoral Injection of Echo Contrast Medium
May Increase the Sensitivity of Testing
for a Patent Foramen Ovale

Maneuver	TEE/TCD (%)
Antecubital	11.4/4.5
Antecubital + Valsalva	18/13.6
Femoral	38.6/36
Femoral + Valsalva	50/50

Risk Stratification Based on PFO Phenotype



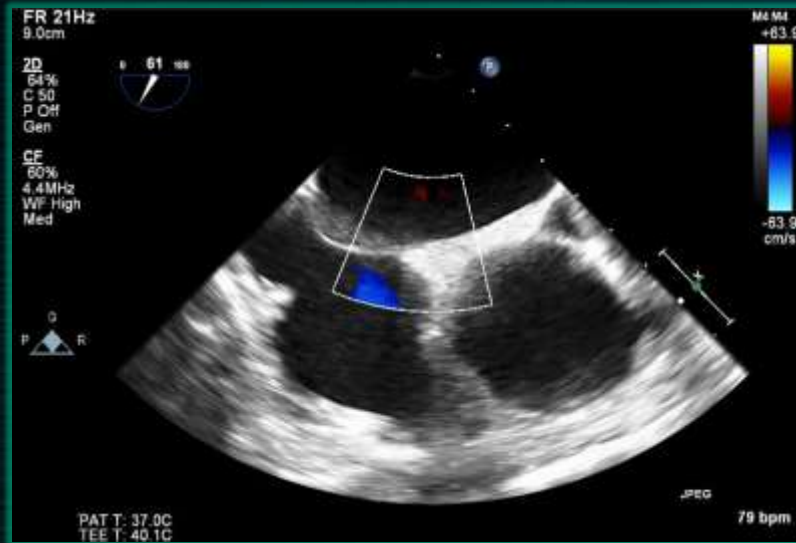
PFO Phenotype: *Low Risk*



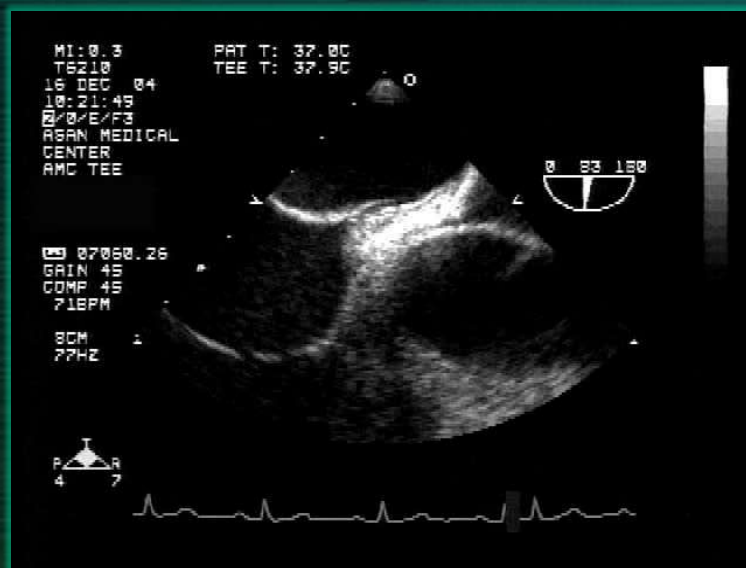
PFO Phenotype: *Low Risk*



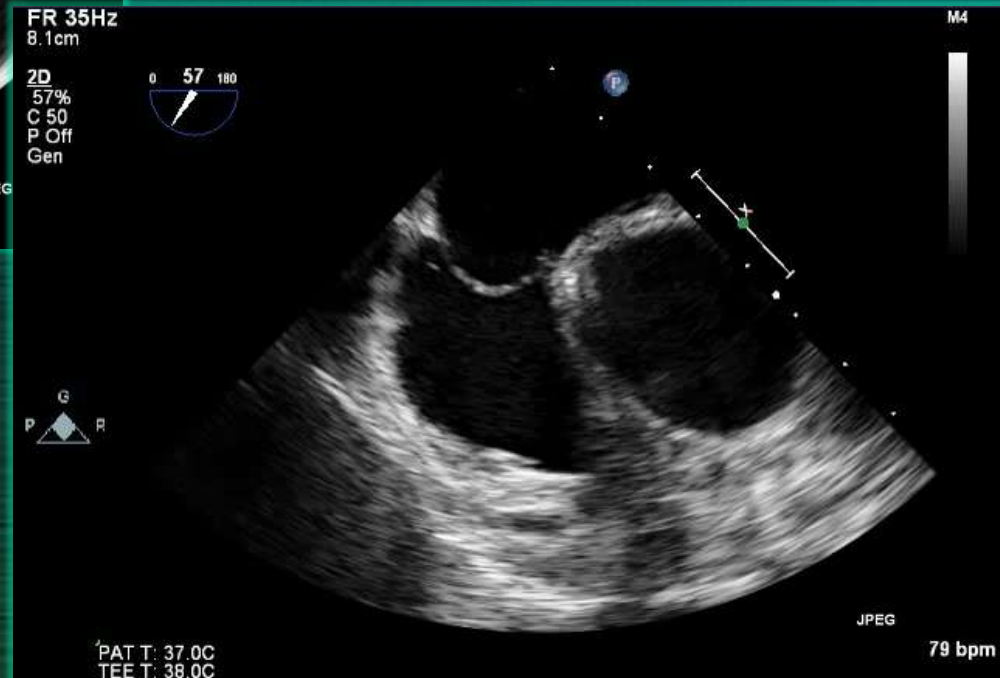
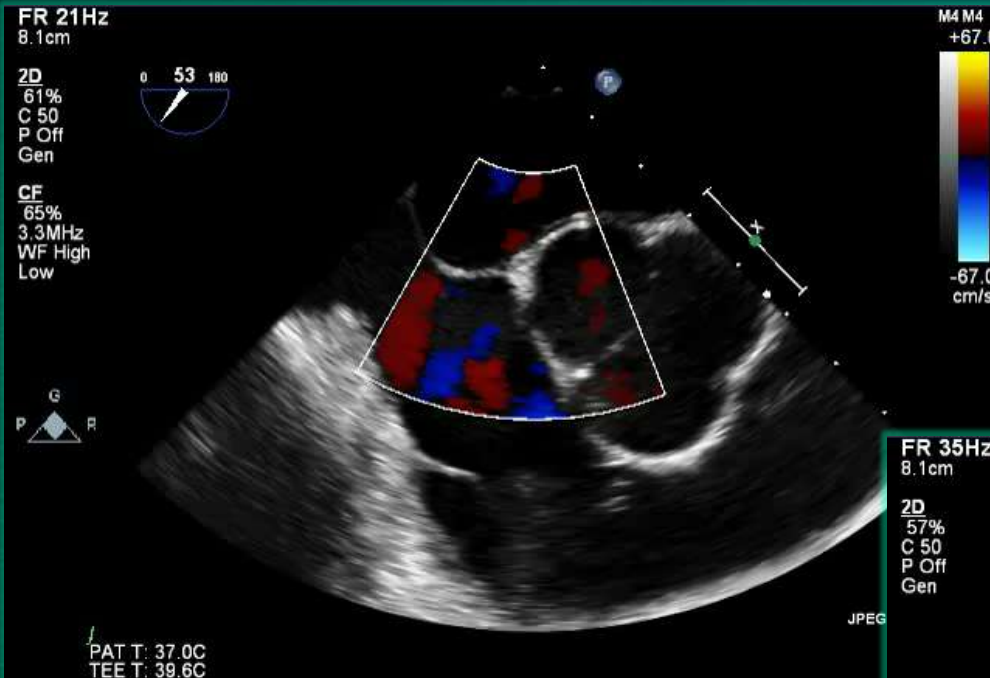
PFO Phenotype: *Low Risk*



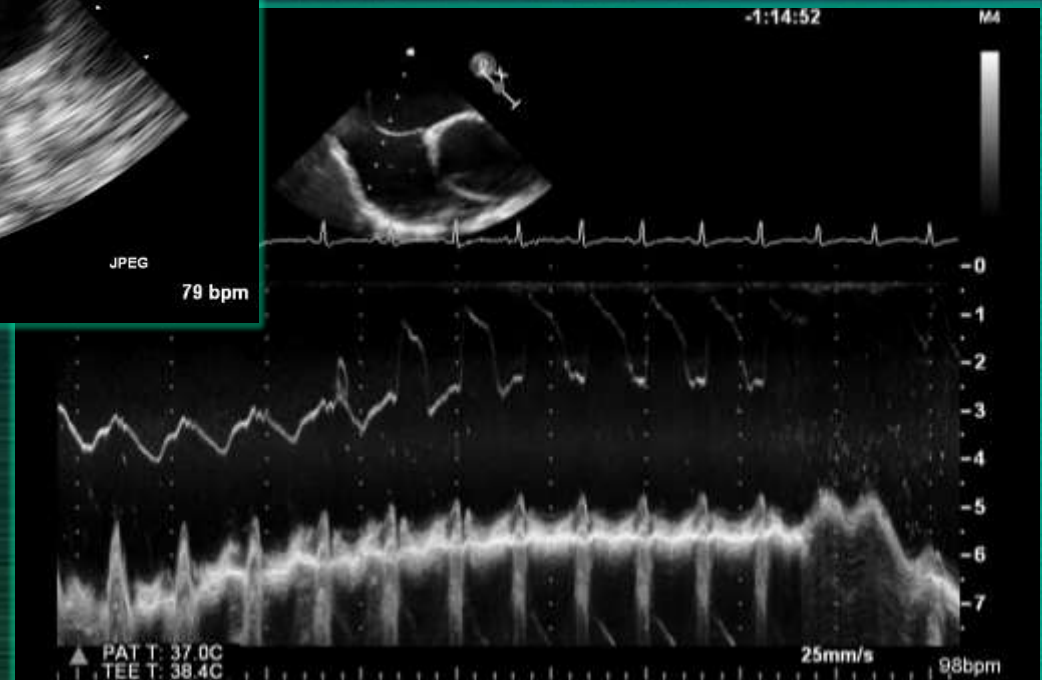
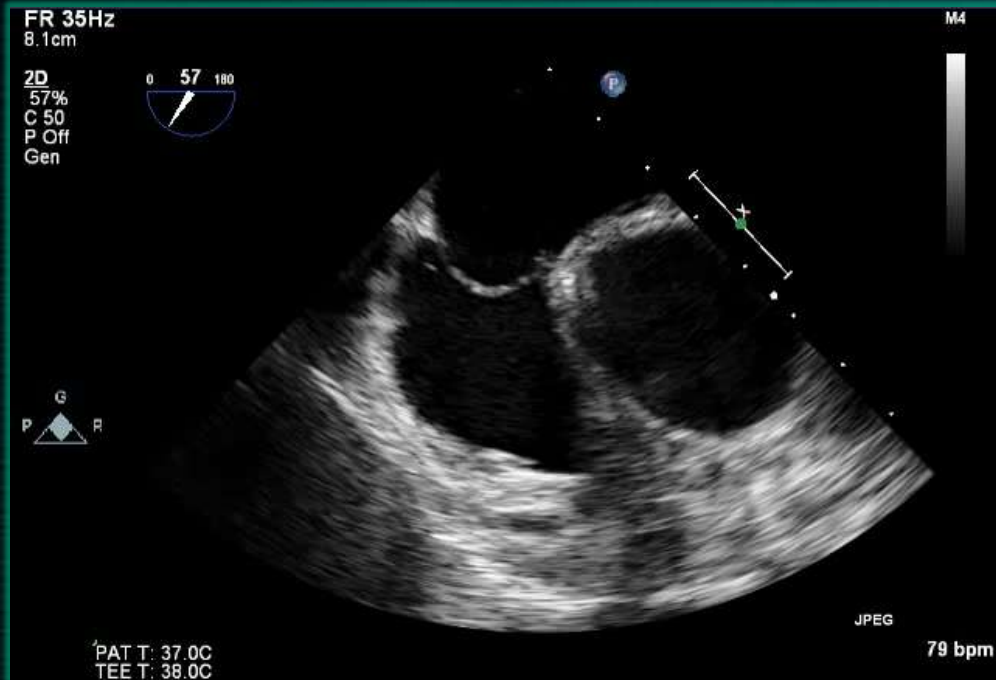
PFO Phenotype: High Risk (Large Shunt)



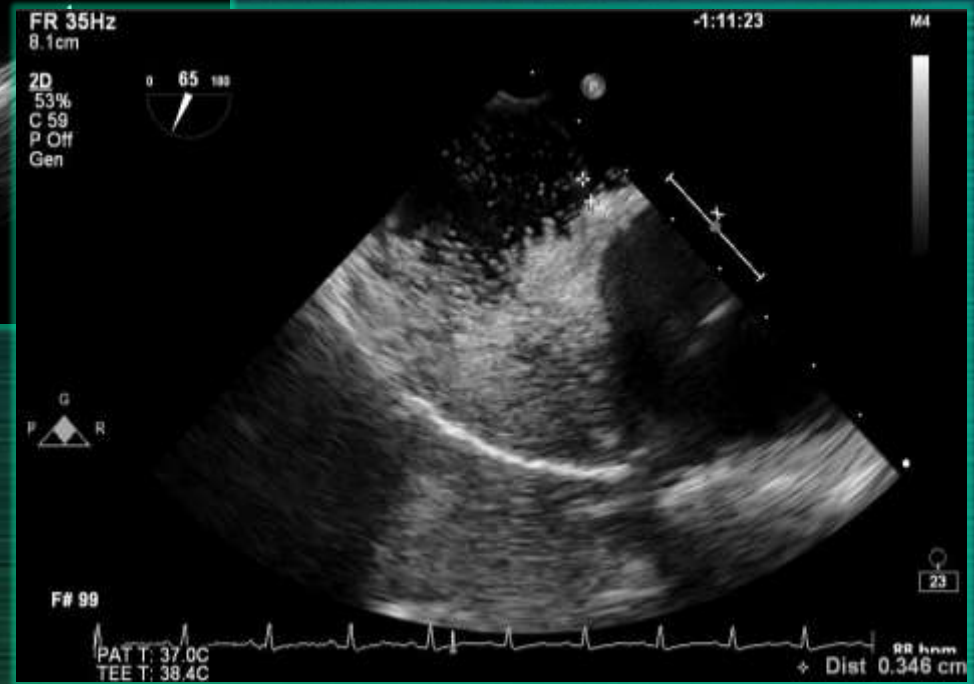
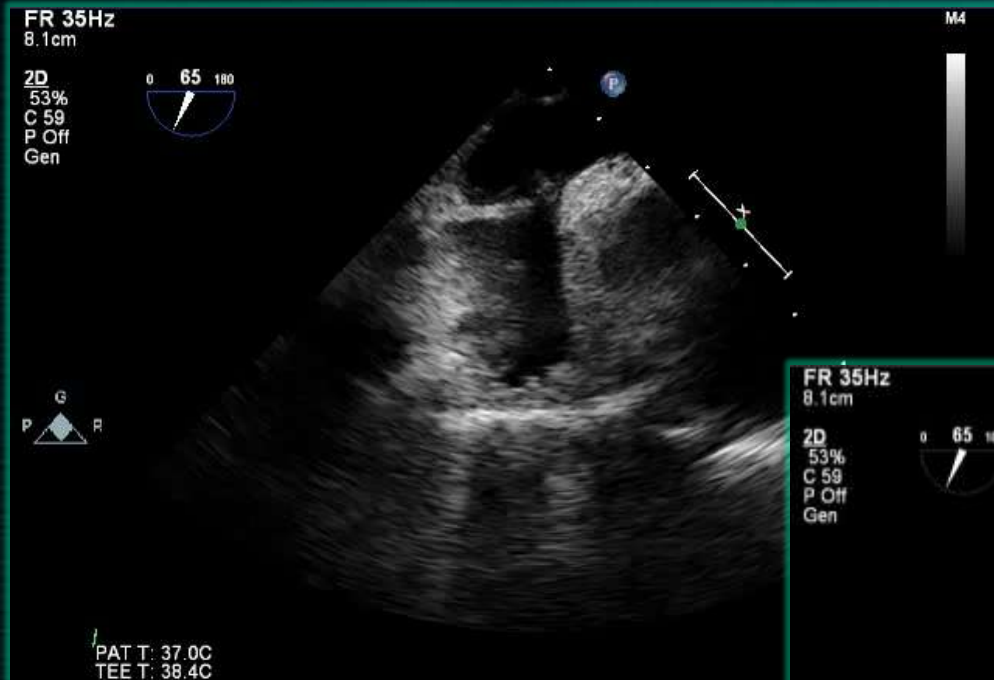
PFO Phenotype: High Risk (Hypermobile Septum)



PFO Phenotype: High Risk (Hypermobile Septum)



PFO Phenotype: *High Risk*



DEvice Closure versus Medical Therapy For SEcoNdary Prevention in Cryptogenic Stroke Patients with High-Risk Patent Foramen Ovale: *DEFENSE-PFO trial*

- A prospective, two arms, single blinded, randomized multi-center trial
- High-risk PFO: PFO ≥ 2 mm, ASA or atrial septal hypermobility
- Primary outcome: stroke recurrence, vascular death, bleeding
- MRI imaging F/U

DEFENSE-PFO

Cryptogenic Stroke Patient with
High-risk Patent Foramen Ovale
(PFO size by TEE \geq 2 mm or
Atrial Septal Hypermobility/Aneurysm)

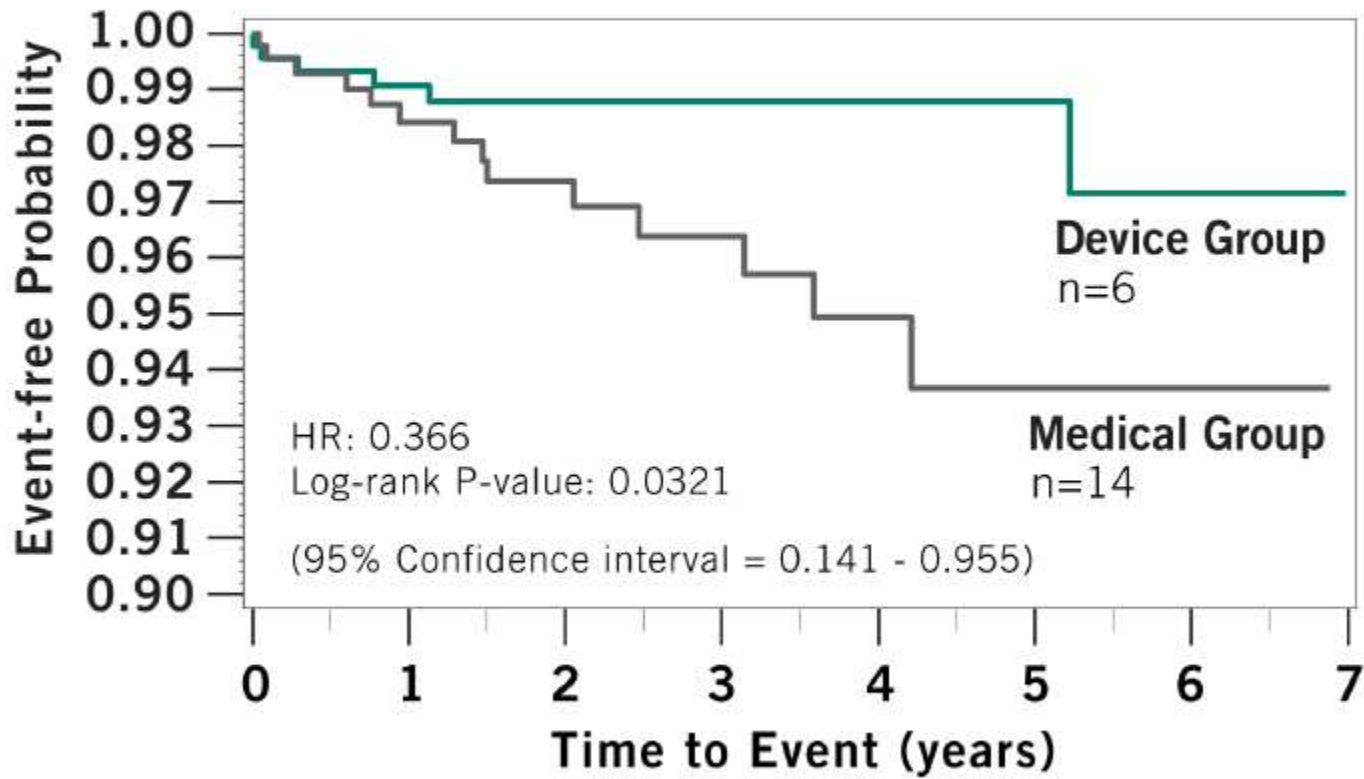
PFO device closure
(Amplatzer Device)

Standard
Medical Treatment

- Recurrent event rate: device group (4%) vs. medical group (15%)
- Statistical power of 80% and attrition rate of 10%
- Each group should have 105 patients.

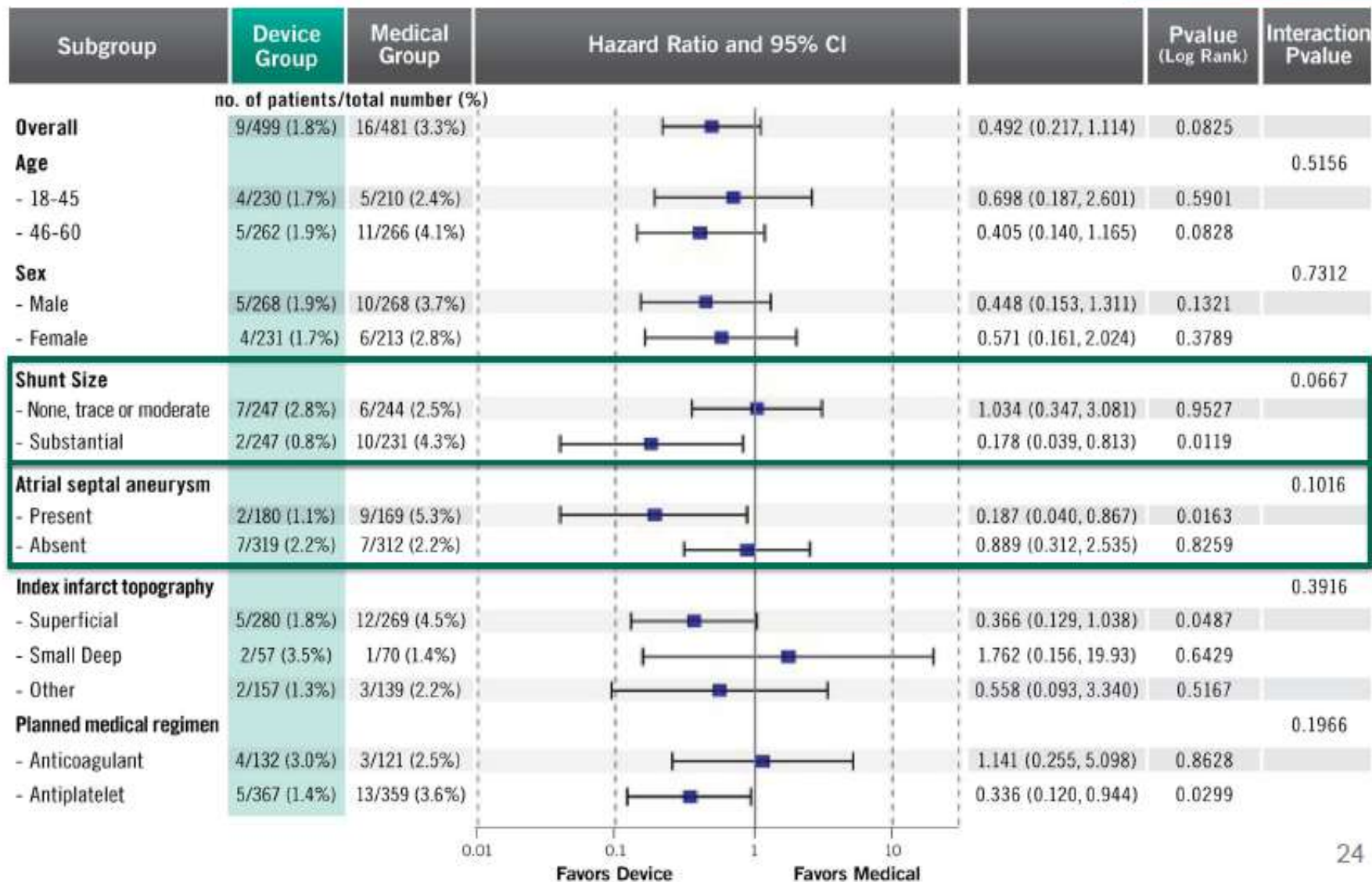
Primary Endpoint Analysis – Per Protocol Cohort

63.4% risk reduction of stroke in favor of device

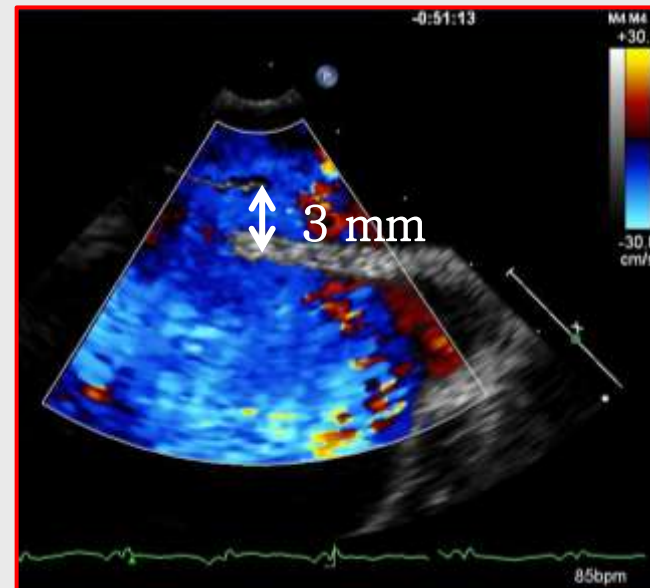
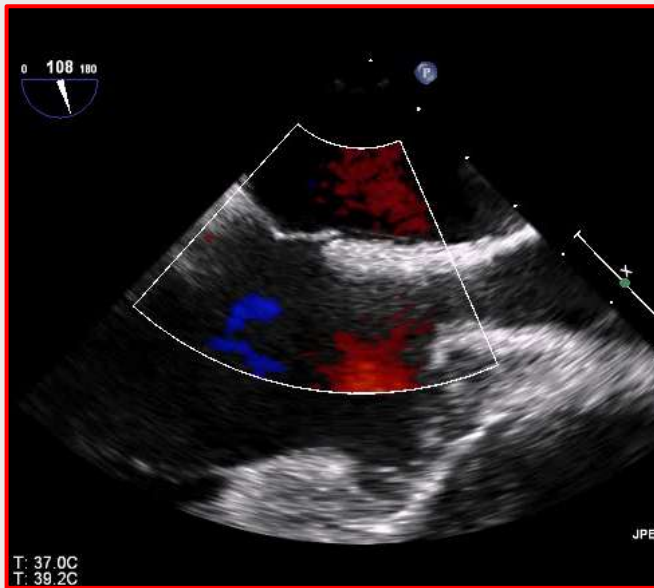
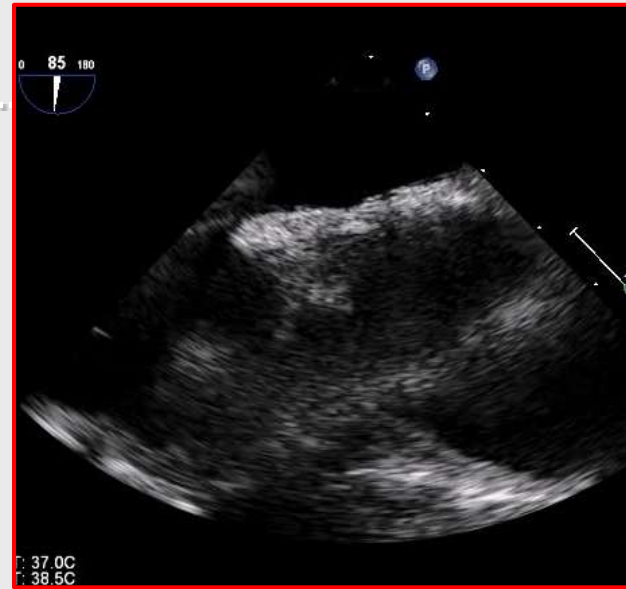
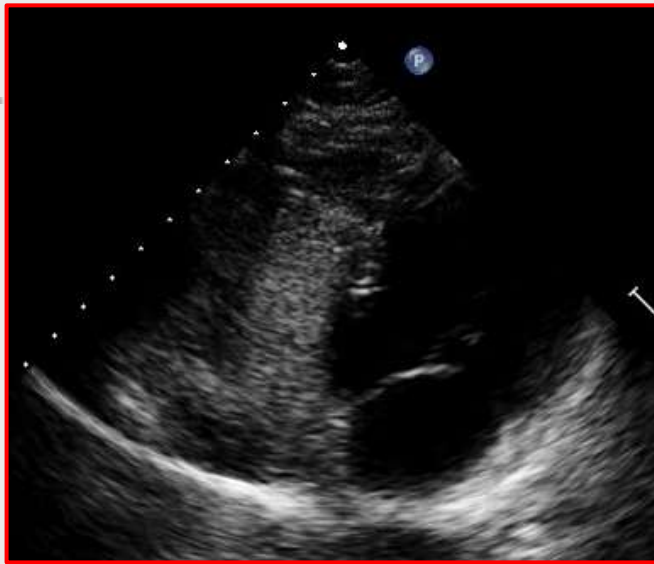


- The Per Protocol (PP) cohort includes patients who adhered to the requirements of the study protocol

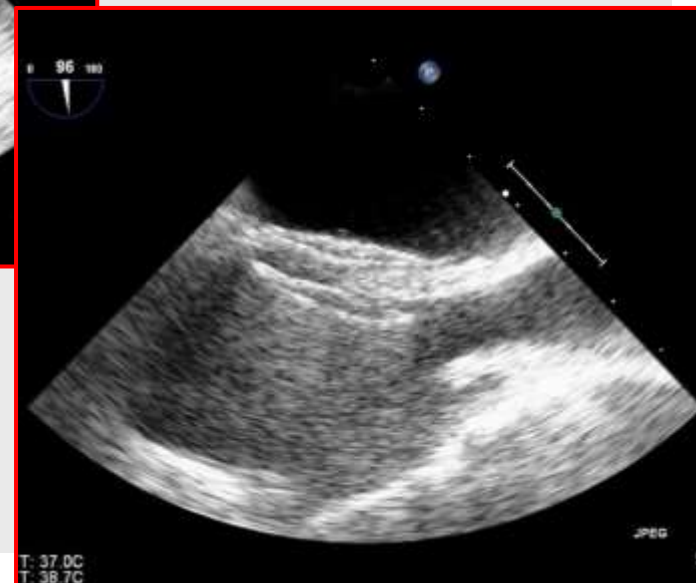
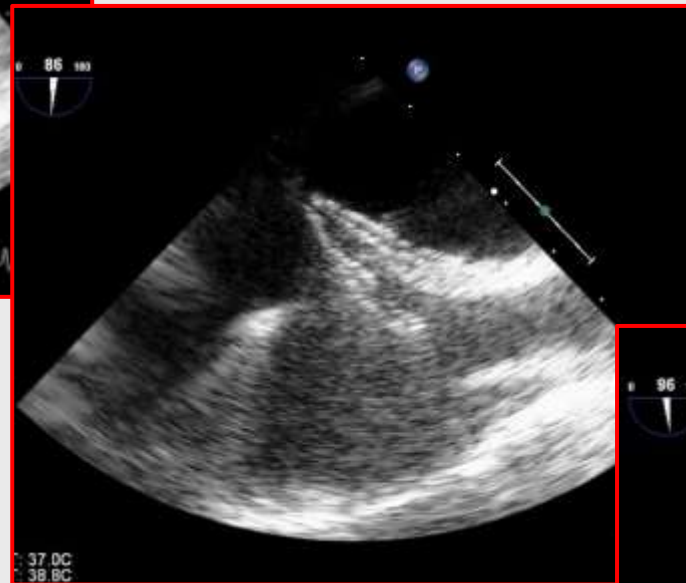
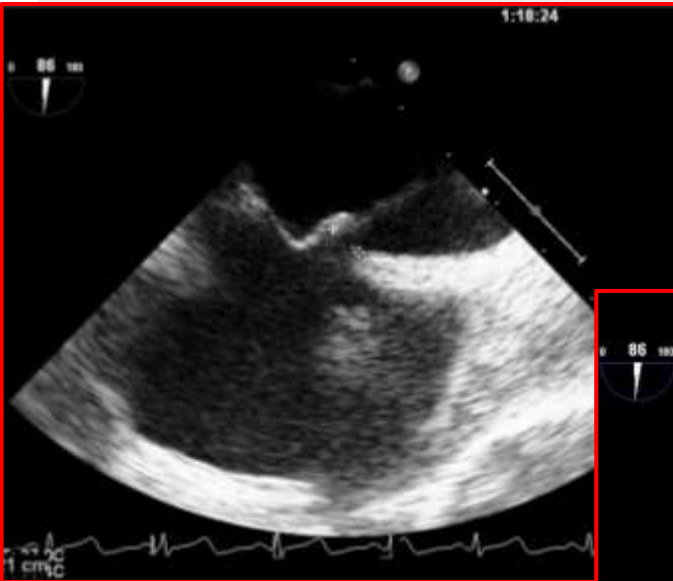
Subpopulation Differential Treatment Effect



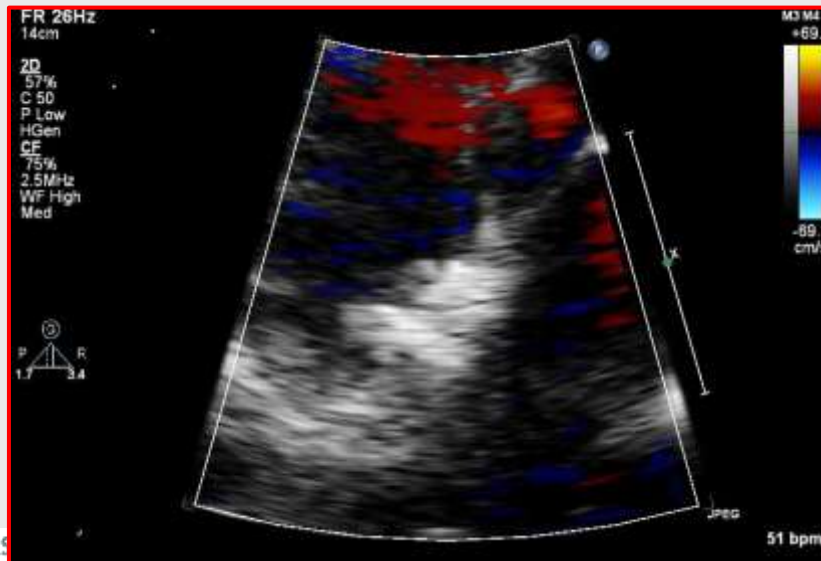
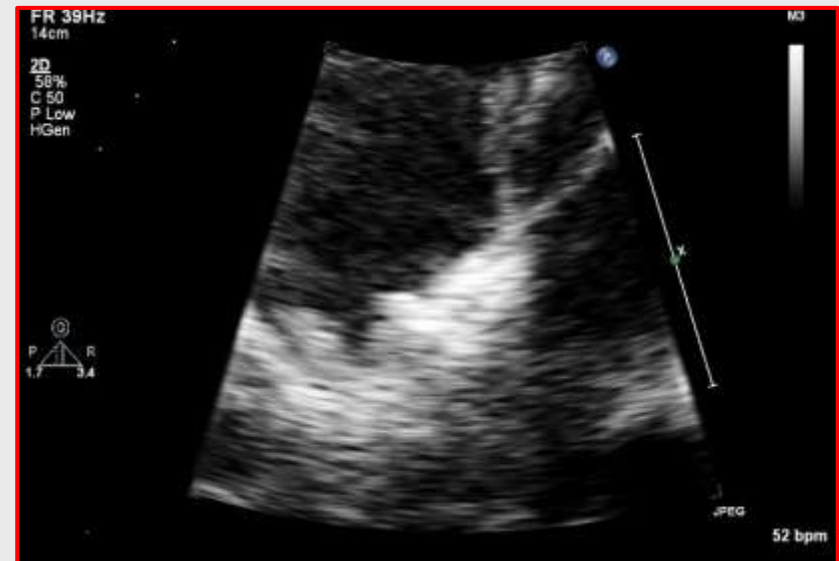
- 38/F, cryptogenic stroke in 2010



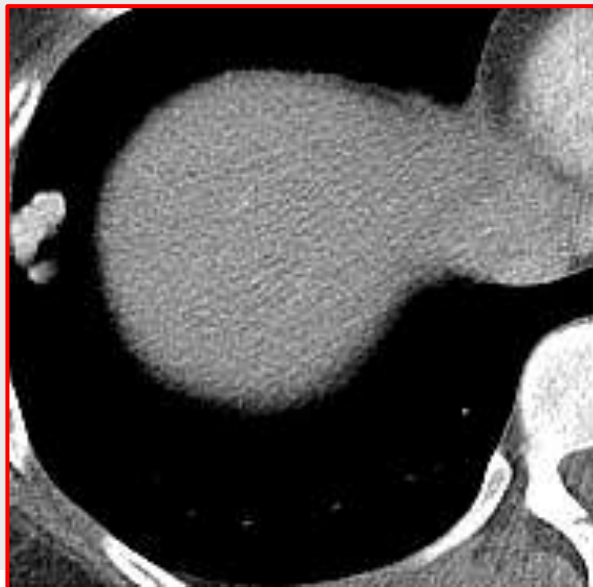
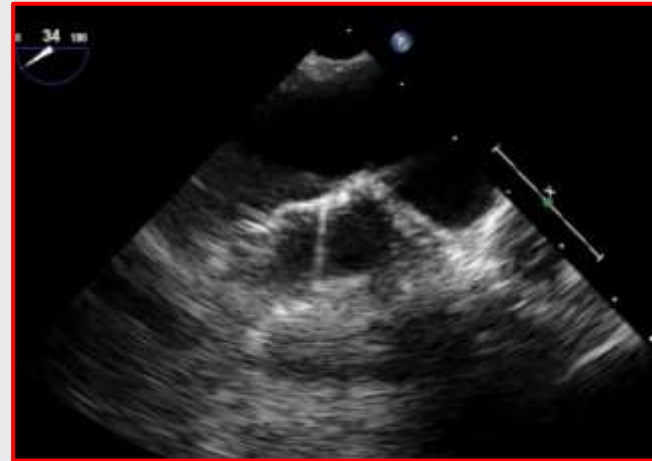
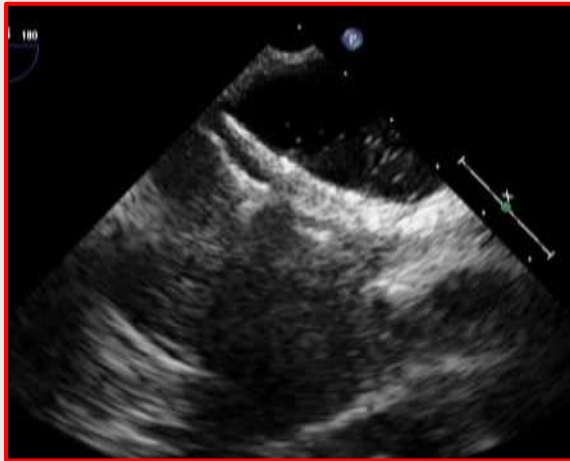
- 38/F, cryptogenic stroke in Feb, 2010
- Underwent PFO device closure in Apr, 2010



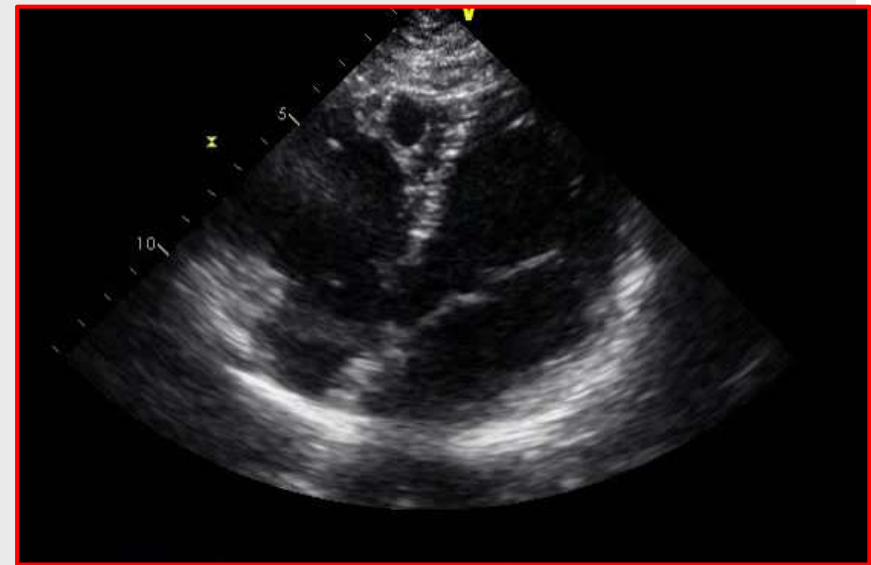
- 38/F, cryptogenic stroke in Feb, 2010
- Underwent PFO device closure in Apr, 2010
- F/U echo in May, 2013



- 38/F, cryptogenic stroke in Feb, 2010
- Underwent PFO device closure in Apr, 2010
- F/U echo in May, 2013

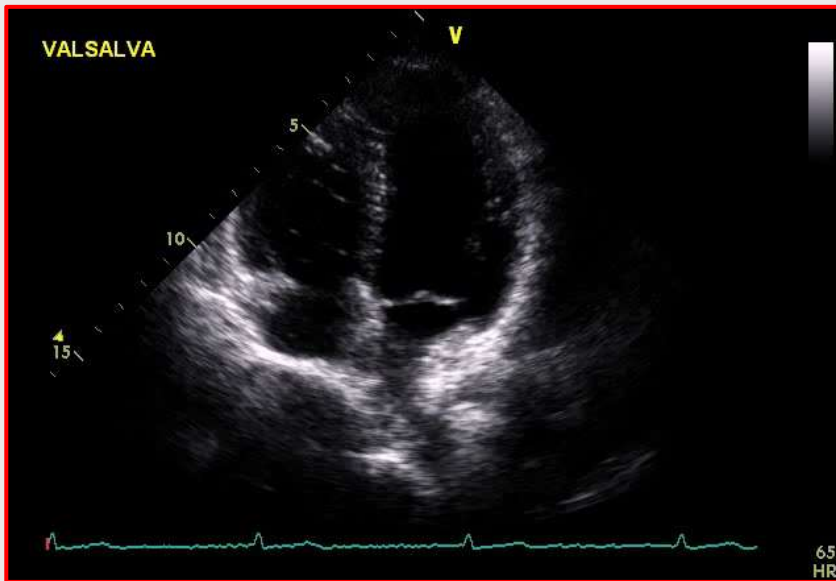


- 38/F, cryptogenic stroke in Feb, 2010
- Underwent PFO device closure in Apr, 2010
- F/U echo in May, 2013
- Closure of pulm AV malformation in Oct 2014

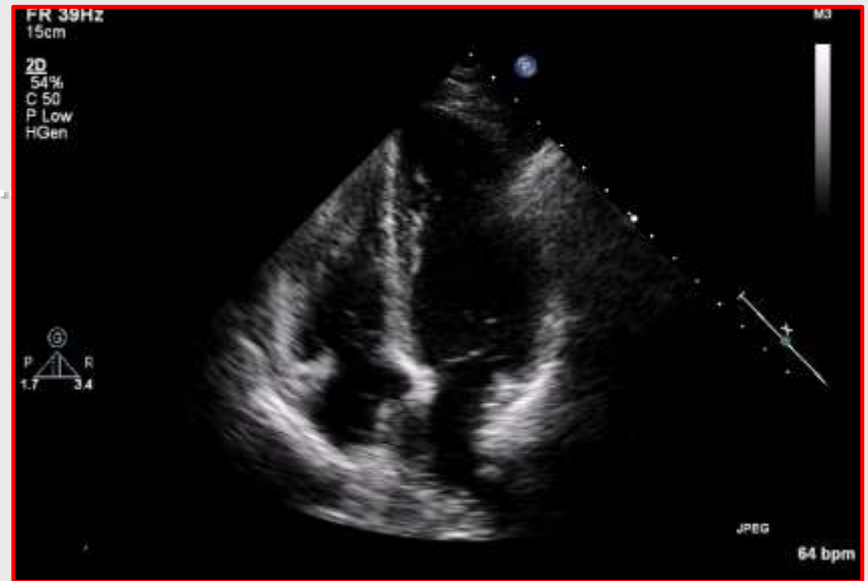


After PFO device closure

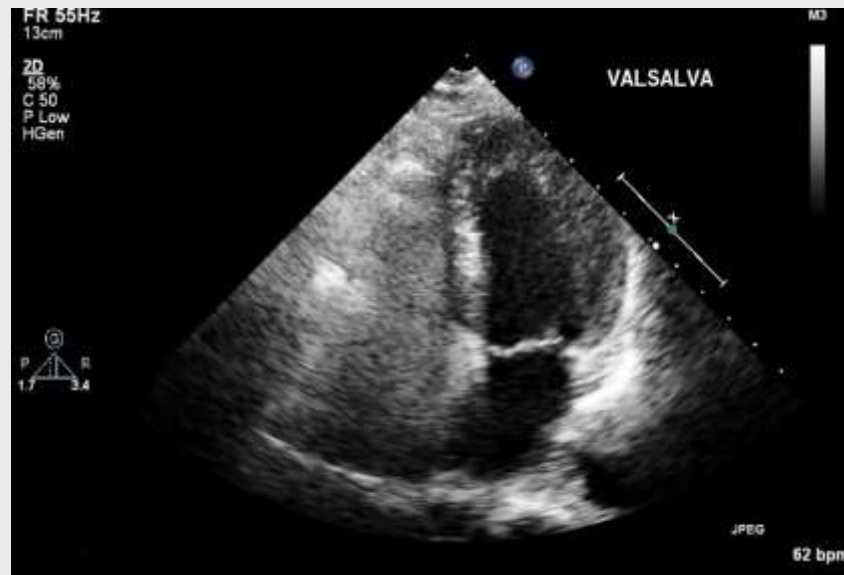
After closure of pulm AV
malformation



Before PFO closure



Immediately after device closure



1 year later

PFO: To Close or Not To

- PFO diagnosis is not easy!
- Team approach (neurologists, cardiac image specialists and interventionalists) is necessary for clinical decision making for secondary prevention
- Risk stratification based on PFO phenotype?

