BMUS

Lung and pleura ultrasound

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Taking pride in caring

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Assume know consolidation

Dependent area
Supine patient
Organification
Air + fluid bronchograms
Minimal aeration
Associated effusion

- Lung ultrasound should be considered as an accurate tool in ruling in lung consolidation when compared with chest radiography.

B-D3-S6 (strong: level B)

- Lung ultrasound may be considered as an accurate tool in ruling out lung consolidation in comparison with chest radiography.

B-D3-S7 (no consensus: level C)

- Use of lung ultrasound as an initial diagnostic strategy in the evaluation of lung consolidation improves outcomes in comparison with chest radiography.

B-D3-S3 (strong: level N/A)

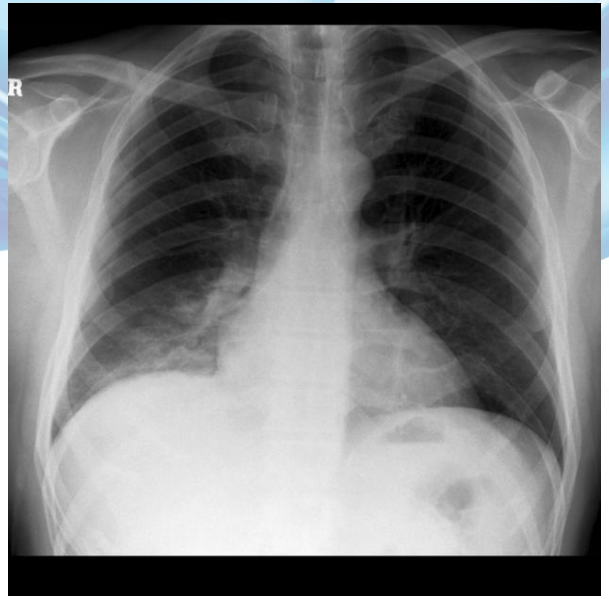
- Ultrasound diagnosis of lung consolidation may be considered as a basic sonographic technique with a steep learning curve.

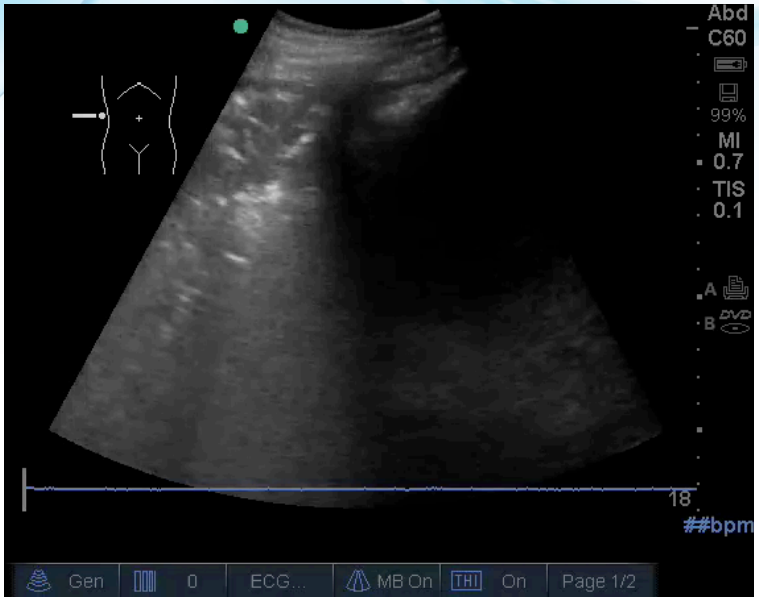
B-D4-S6 (strong: level B)

- Lung ultrasound should be considered in the detection of radio-occult pulmonary conditions in patients with pleuritic pain.

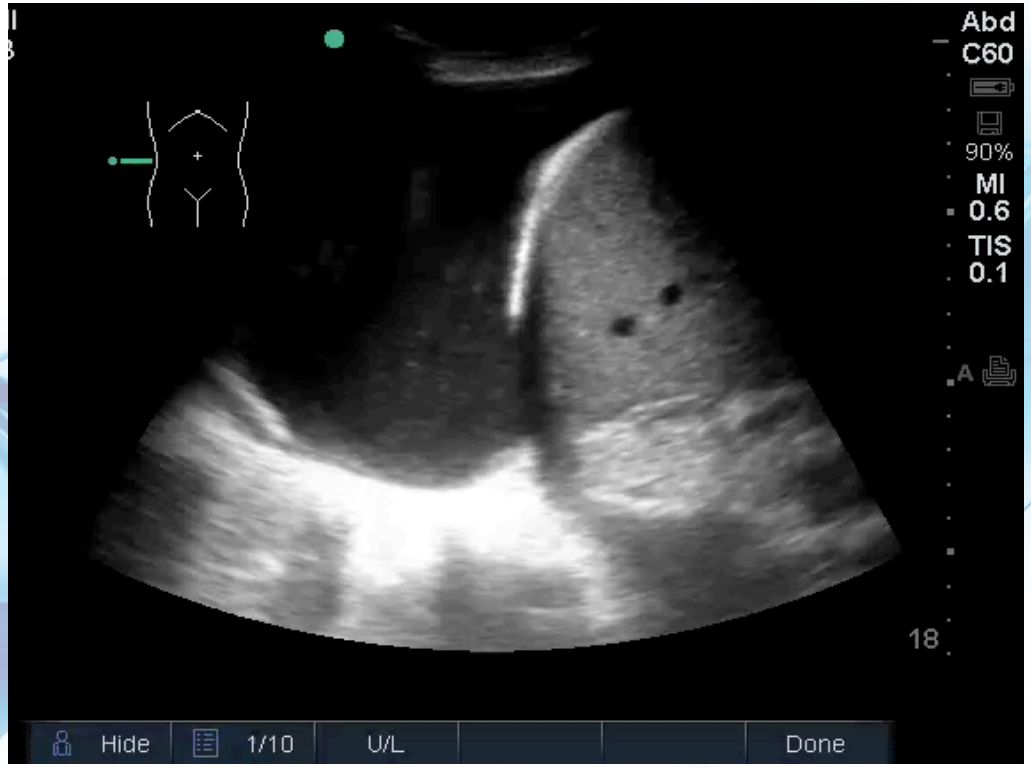
BMUS Don’t have CAP “normal” CXR…

- We all know what CXR “misses”
- See on CT all time
- US comparable sensitivity *to PAL*





Assume pleural effusions



- Black anechoic space
- Pleural thickening
- Associated consolidation
- Debris
- Fibrin stranding
- Jellyfish sign

B-D4-S7 (strong: level A)

- In opacities identified by chest radiography, lung ultrasound should be used because it is more accurate than chest radiography in distinguishing between effusion and consolidation.

BMUS Tips: effusion and consolidation

- White base CXR level 1 indication US
- Gravity: PLAPS
- Aeration and recruitment, PEEP
- All pneumococcus consolidation= lung abscess
- PE's are consolidation
- Can't say much more on effusion or consolidation without clinical info

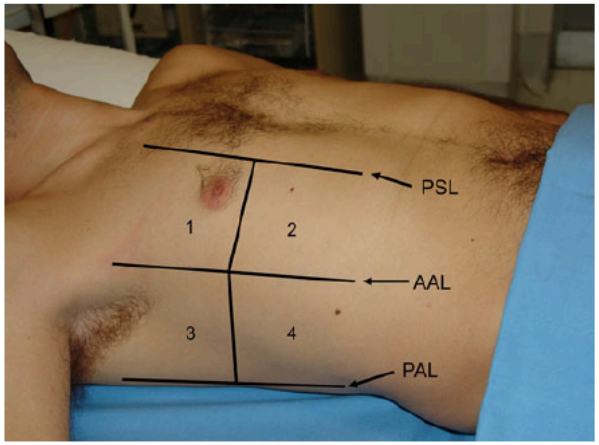


Fig. 2 The four chest areas per side considered for complete eight-zone lung ultrasound examination. These areas are used to evaluate for the presence of interstitial syndrome. Areas *1* and *2* denote the upper anterior and lower anterior chest areas, respectively. Areas *3* and *4* denote the upper lateral and basal lateral chest areas, respectively. *PSL* parasternal line, *AAL* anterior axillary line, *PAL* posterior axillary line (modified from Volpicelli et al. [19])

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Today

- Context to POC US
- Interstitial syd
- ARDS vs hydrostatic pulmonary oedema
- PTX
- PE
- Other applications

Resources

- Lichtenstein: BLUE FALLS protocols
- Volpicelli 2012 guidelines (No update?)
- RCR
- CUSIC FICE
- ACEP
- IFEM

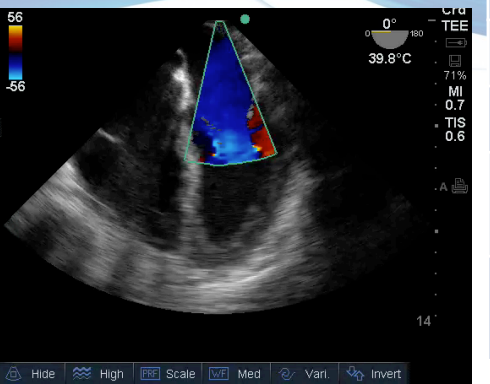
https://www.ncbi.nlm.nih.gov/pubmed/26033127
https://www.ncbi.nlm.nih.gov/pubmed/22392031
https://www.ics.ac.uk/ICS/cusic.aspx
https://www.ics.ac.uk/ICS/fice.aspx
https://www.rcr.ac.uk/sites/default/files/documents/BFCR%2814%2917_Standards_ultrasound.pdf

INTERNATIONAL FEDERATION FOR EMERGENCY MEDICINE

POC vs departmental

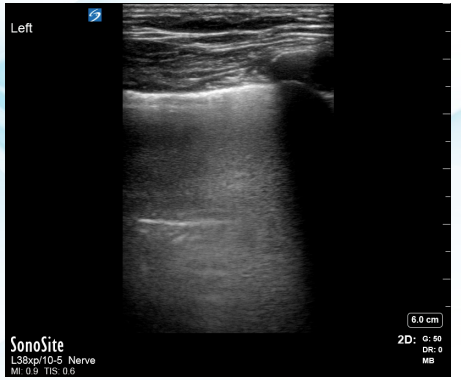
- Chest US a grey area?
- Evolving no clear referral pathway
- Adjuncts CXR, CT and biomarkers
- Most colleagues still want CXR!

POC	Departmental
Clinician led	Visiting specialist
Clinical question	Often poorly clarified indication
Binary answer	Want comprehensive study
Time dependent	A delivered service
May be repeated	Generally a one off
Supported by sub-specialists	Delivered by specialty. “Definitive”.
Additional tests or imaging	Discussed beforehand, best shot at answer



A “new” artifact: the B line

- Normal= slide and A lines
- B lines
- >3 in 2 adjacent intercostals= AIS
- Associated pleural change
- Thickening interlobular septae



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B line: from the man himself

1. Comet tail artifact
2. Arises from pleural line
3. Hyperechoic
4. Well defined
5. Divergent
6. Dominant over A lines
7. Moves with lung sliding (if present)

Lichtenstein D. Chest 2008;134:117- 25

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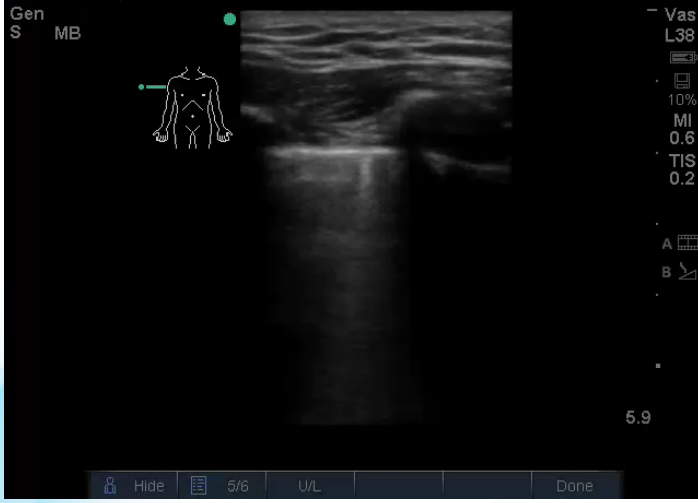
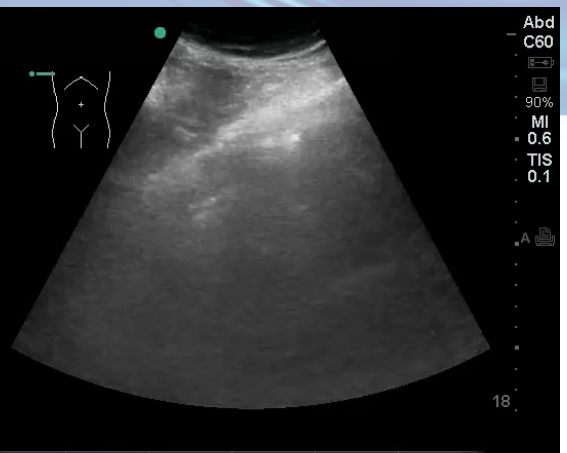
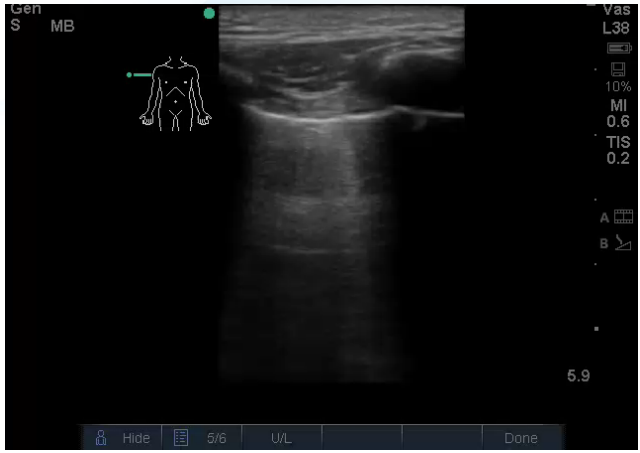
Terminology

- B line one type comet tail artifact
- “Rockets” multiple B lines
- B7 7mm apart (moderate severity, interlobular septal thickening)
- B3 3mm apart (ground glass CT)
- Birolleau variant (severe, white out)







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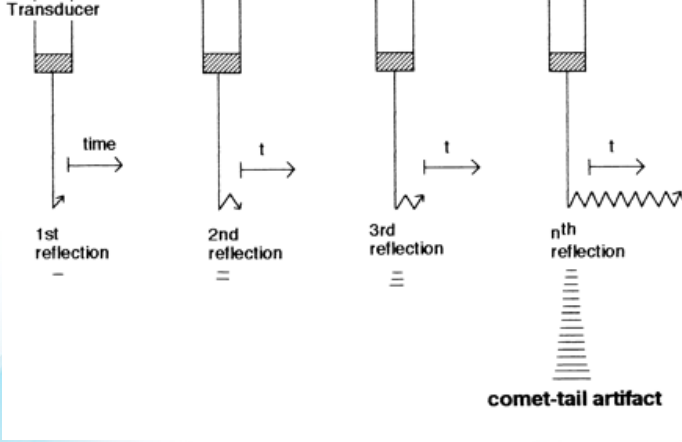
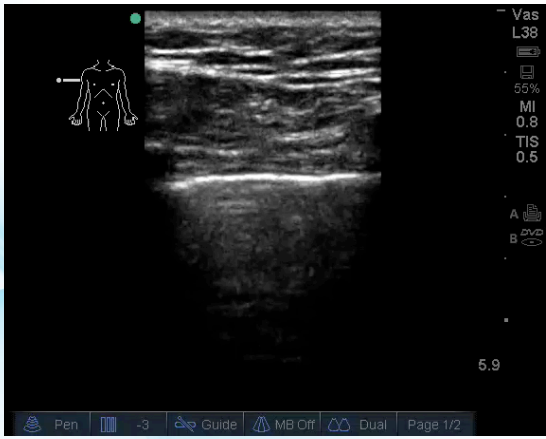
Why do we get B lines?

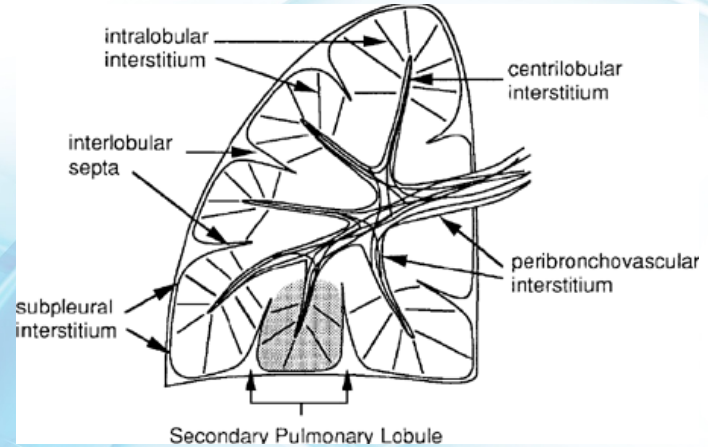


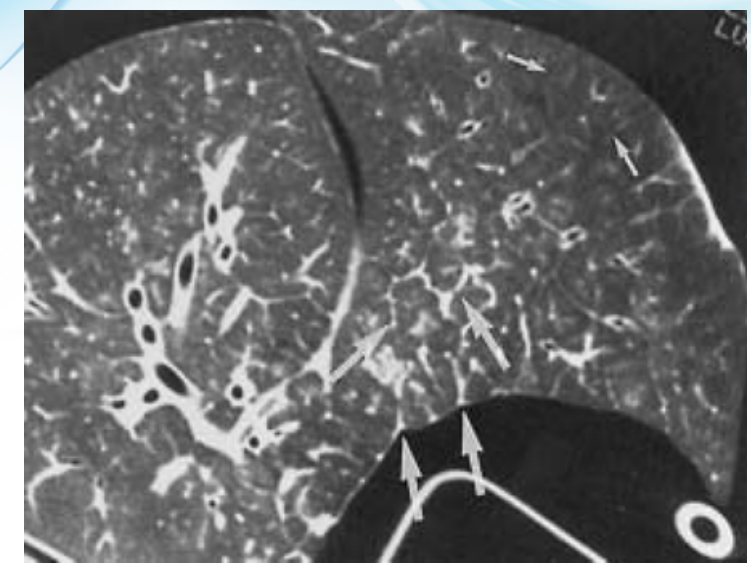
- Not entirely sure!
- Not simply propagation (Z line)
- Don't fade distance
- US attenuated
- Likely resonance
- Variant ring down artifact
- "Streaks" off protein or crystals
- Telling us about pleura/ periphery?



B line-thickening of interlobular septae

Arrows interlobular Septae enclosing a (secondary) lobule





What is a B line?

An idiot with a stethoscope is an idiot with US…

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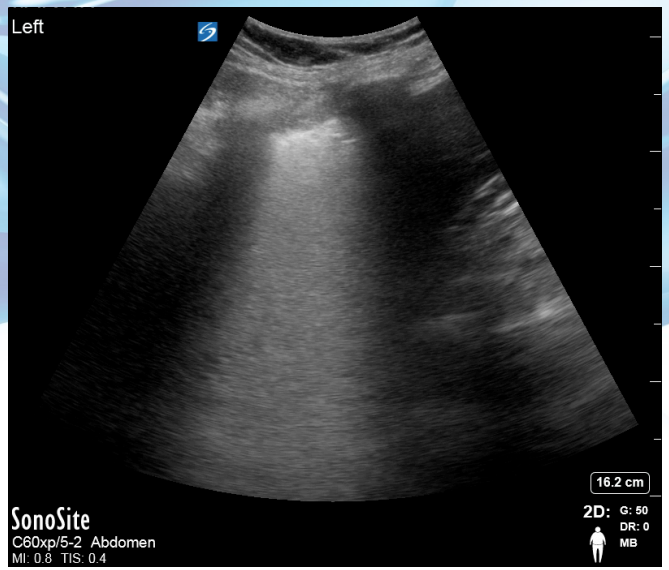
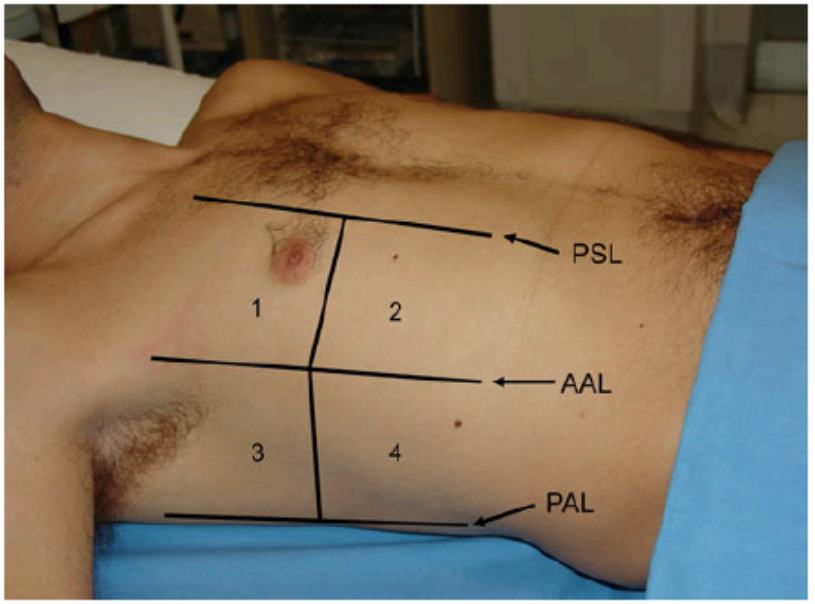
Alveolar interstitial syndrome (AIS)

- 3 or more B lines
- 2 or more adjacent IC spaces





Volpicelli et al. ICM 2012

BMUS Context: clinician advantage!

- Blines + 83 + CCF+ ST elevation= pulmonary oedema
- Blines + 25+ sepsis+ temp/WCC/CRP= CAP
- Lateralising and heterogenous
- +- consolidation/ PLAPS
- Echo findings
- Bloods

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B lines causes: interstitial changes

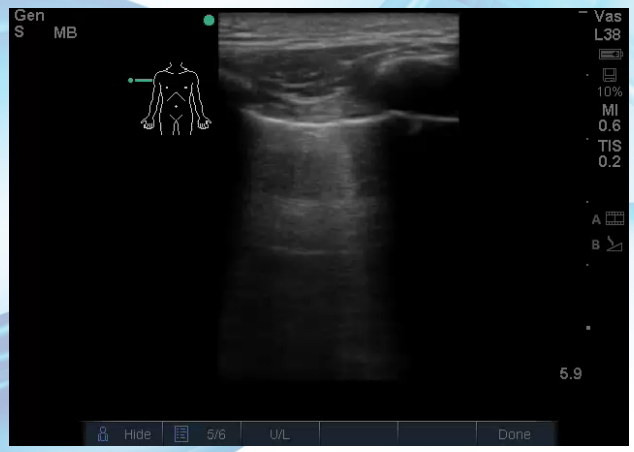
- Few “normal” esp dependent
- > 3 in >2 spaces AIS
- ARDS
- Pneumonia (+remote consolidation)
- LVF hydrostatic acute pulmonary oedema (HAPE)
- Lung fibrosis
- Malignancy
- Pneumonitis
- Atelectasis
- Contusion

B lines non-specific sign AIS

Lung Ca
RadioTx

Few: normal

Cath lab, IHD



Failure to wean
20l +ve

Aspiration

"ARDS"

O/P heart
failure clinic

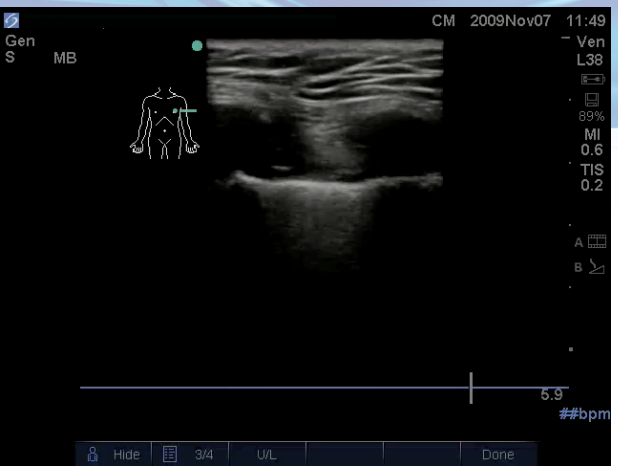
VAP

Confused
Z line

Chest clinic
Fibrosis
Pleura disease

B lines some tips

- B lines exclude PTX
- Main differential LVF vs ARDS
- *Acute* SOB largely excludes resp cause (COPD/ asthma predominant A lines)
- Number= severity
- Disappear as get better
- Use linear array anteriorly
- Look worse low f probes

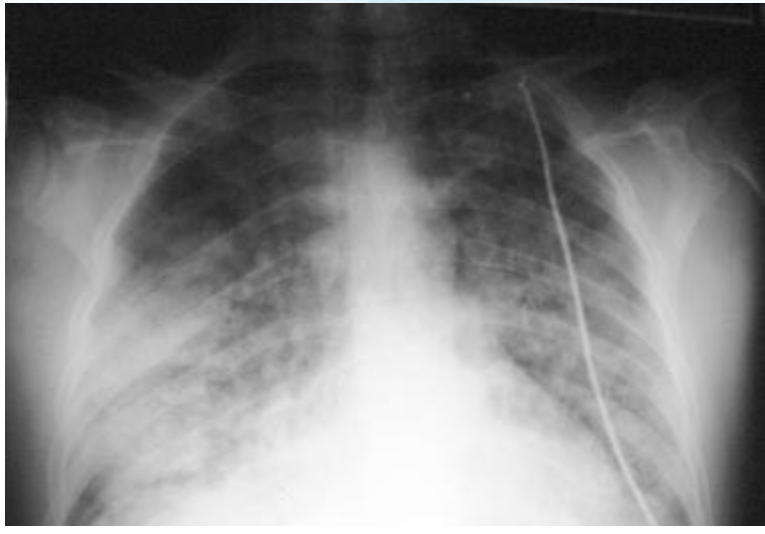


Z line

HAPE vs ARDS

- Very difficult CXR
- Relatively easy US
- Interstitial syd and B lines
- Definition

ARDS sower onset and resolution
More homogenous, CCF perihilar
CCF “predominance” upper zones
CCF cardiomegaly
Often supine patient
Pleural effusion universal in CCF



https://www.med-ed.virginia.edu/courses/rad/chest/f19ardsVsChf.html

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The Radiologic Distinction of Cardiogenic and Noncardiogenic Edema

Improvement in the ability to determine the specific cause of any given case of pulmonary edema would lead to more rapid and definitive treatment. "Wedge" pressures and measurements of cardiac output derived from Swan-Ganz catheterization assist in making this determination, but the procedure is invasive, expensive, associated with complications, and not infrequently inaccurate. A plain chest film is, however, almost invariably available in all patients with pulmonary edema, and as shown in this study, the cause of the edema can be determined with a high degree of accuracy by careful attention to certain radiographic features. An independent two-observer study was performed on 216 chest radiographs of 61 patients with cardiac disease, 30 with renal failure or overhydration, and 28 with capillary permeability edema. Three principal and seven ancillary features have been identified, all of which are statistically significant and permit the cause of the edema to be determined correctly in a high percentage of cases. The three principal features are distribution of pulmonary flow, distribution of pulmonary edema, and the width of the vascular pedicle. The ancillary features are pulmonary blood volume, peribronchial cuffing, septal lines, pleural effusions, air bronchograms, lung volume, and cardiac size. Differing constellations of these features occur, each of which is characteristic of a specific type of edema. Overall accuracy of diagnosis in this study ranged from 86% to 89%. The highest accuracy was obtained in distinguishing capillary permeability edema from all other varieties (91%), and the lowest in distinguishing chronic cardiac failure from renal failure (81%).

Eric N. C. Milne[1]
Massimo Pistolesi[2]
Massimo Miniati[2]
Carlo Giuntini[3]

AJR 144:879–894, May 1985
0361–803X/85/1445–0879

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TABLE 3: **Radiographic Features of Pulmonary Edema**

	Cardiac	Renal	Injury
Heart size	Enlarged	Enlarged	Not enlarged
Vascular pedicle	Normal or enlarged	Enlarged	Normal or reduced
Pulmonary blood flow distribution	Inverted	Balanced	Normal or balanced
Pulmonary blood volume	Normal or increased	Increased	Normal
Septal lines	Not common	Not common	Absent
Peribronchial cuffs	Very common	Very common	Not common
Air bronchogram	Not common	Not common	Very common
Lung edema, regional distribution (horizontal axis)	Even	Central	Peripheral
Pleural effusions	Very common	Very common	Not common

Note.—Each factor listed has been shown to have statistical significance in determining which type of edema is present.

Milne EC et al. AJR 1985

HAPE vs ARDS

- Common acute dilemma
- “Impossible” CXR!
- ARDS requires absent ↑ LAP + acute infiltrates
- Acute infiltrates LVF + ARDS very similar
- ↑ LAP depends on circumstances
- Could US help?

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ARDS, acronyms and the Pinocchio effect

How can there be a biomarker for what is imaginary?

Table 1. ARDS Berlin definition.

The Berlin definition of acute respiratory distress syndrome	
Timing	Within 1 week of a known clinical insult or new or worsening respiratory symptoms
Chest imaging[a]	Bilateral opacities — not fully explained by effusions, lobar/lung collapse, or nodules
Origin of edema	Respiratory failure not fully explained by cardiac failure or fluid overload. Need objective assessment (e.g., echocardiography) to exclude hydrostatic edema if no risk factor present
Oxygenation[b]	
Mild	200 mmHg < PaO_2/FIO_2 ≤300 mmHg with PEEP or CPAP ≥5 cmH_2O[c]
Moderate	100 mmHg < PaO_2/FIO_2 ≤200 mmHg with PEEP ≥5 cmH_2O
Severe	PaO_2/FIO_2 ≤100 mmHg with PEEP ≥5 cmH_2O

Abbreviations: CPAP, continuous positive airway pressure; F_IO_2, fraction of inspired oxygen; PaO_2, partial pressure of arterial oxygen; PEEP, positive end-expiratory pressure; [a]Chest radiograph or computed tomography scan; [b]If altitude is higher than 1,000 m, the correction factor should be calculated as follows: [PaO_2/FIO_2_(barometric pressure/760)]; [c]This may be delivered noninvasively in the mild acute respiratory distress syndrome group.

Radiography

Chest radiograph findings of ARDS vary widely depending on the stage of the disease. The most common chest radiograph findings are bilateral, predominantly peripheral, somewhat asymmetrical consolidation with air bronchograms. Septal lines and pleural effusions, however, are uncommon. Differential diagnosis considerations include pneumonias such as those due to aspiration, diffuse alveolar hemorrhage, and pulmonary edema of any cause. (See the images below.)[10, 11, 12]

findings are an integral part of the diagnosis. In fact, the Berlin definition statement underlined the limits of chest radiographs, recommending that chest radiograph criteria should be better clarified by creating a set of example radiographs [1, 3].

http://err.ersjournals.com/content/23/134/519.full

http://emedicine.medscape.com/article/362571-overview#a19

HAPE vs ARDS

	ALI/ARDS	APE
AIS	100%	100%
Pleural line abnormalities	100%	25%
Reduction or absence of lung sliding	100%	0%
"Spared areas"	100%	0%
Consolidations	83.3%	0%
Pleural effusion	66.6%	95%
"Lung pulse"	50%	0%

Conclusion: Pleuroparenchimal patterns in ALI/ARDS do find a characterization through ultrasonographic lung scan. In the critically ill the ultrasound demonstration of a dyshomogeneous AIS with spared areas, pleural line modifications and lung consolidations is strongly predictive, in an early phase, of non-cardiogenic pulmonary edema.

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	Cardiac	Renal	Injury
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Note.—Each factor listed has been shown to have statistical significance in determining which type of edema is present.

Copetti R. Cardiovasc Ultrasound 2008;6:16

ARDS vs Hydrostatic APE

Linear array probe
Harsh settings
5-6 cm

AIS
? Hydrostatic APE
? ARDS

ARDS

Pleural abnormalities
Spared patches
Subpleural consolidation
PLAPS
2/3 pleural effusion
Lung pulse
Dependent preference

Hydrostatic APE

Homogenous
No sparing
All areas
95% pleural effusion
No consolidation

Copetti R. Cardiovasc Ultrasound 2008;6:16

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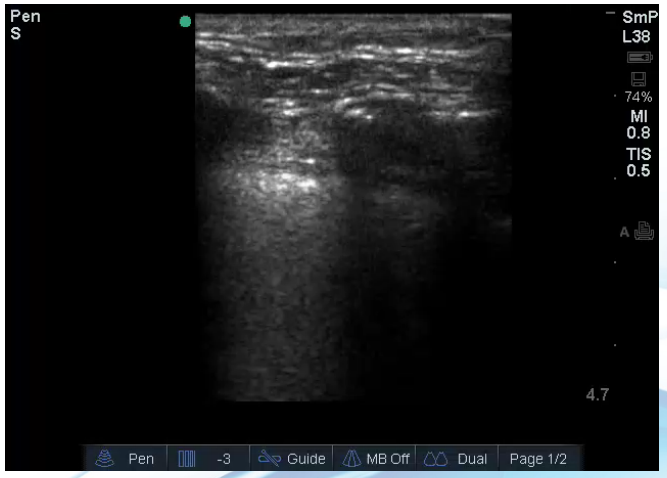

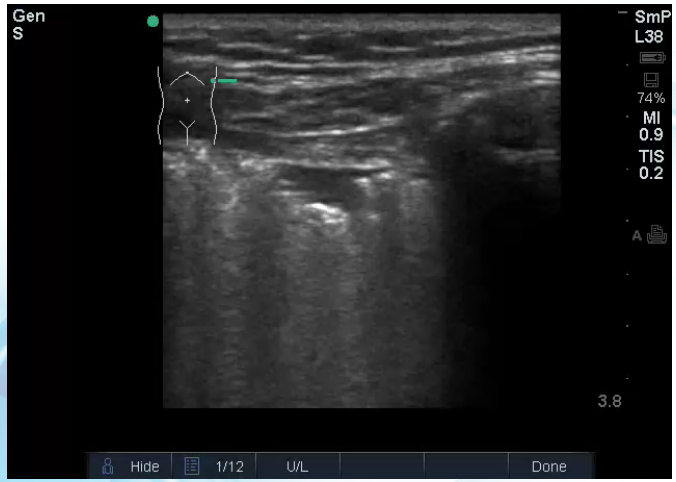

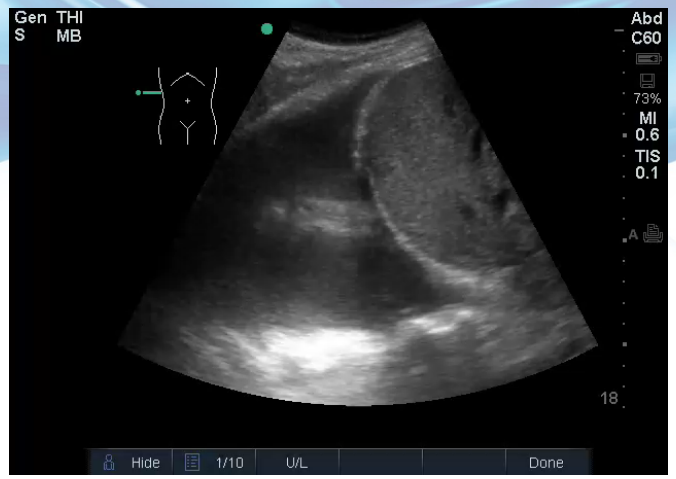

ARDS

- Pleural abnormalities
- Spared patches
- Subpleural consolidation
- PLAPS
- 2/3 pleural effusion
- Lung pulse
- Dependent preference

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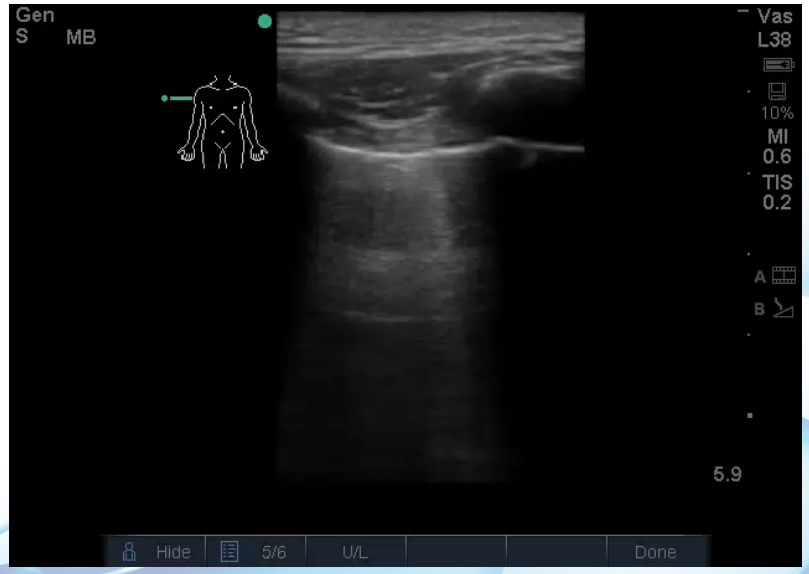
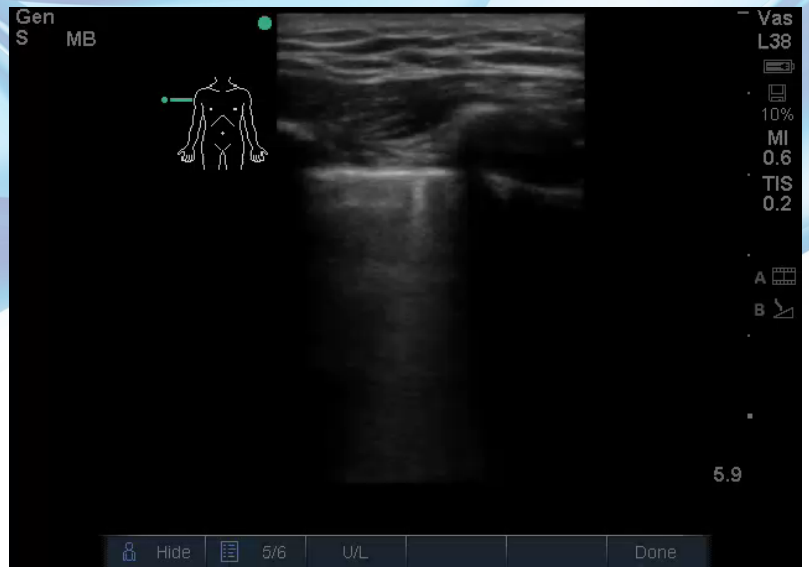
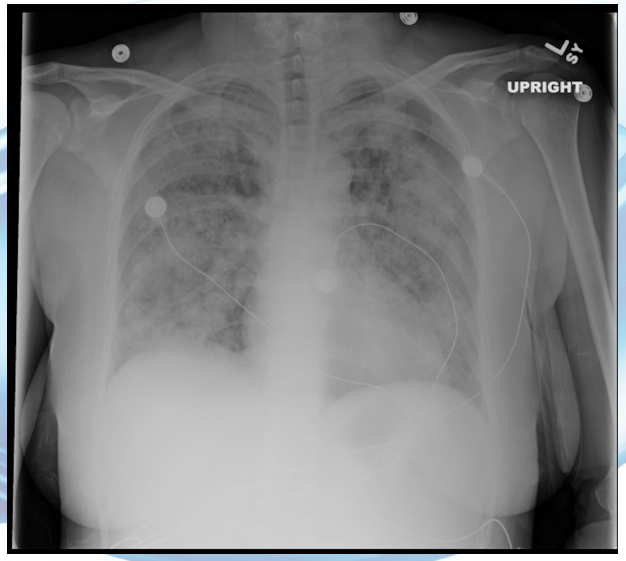




Hydrostatic APE

- Homogenous
- No sparing
- All areas
- 95% pleural effusion
- No consolidation

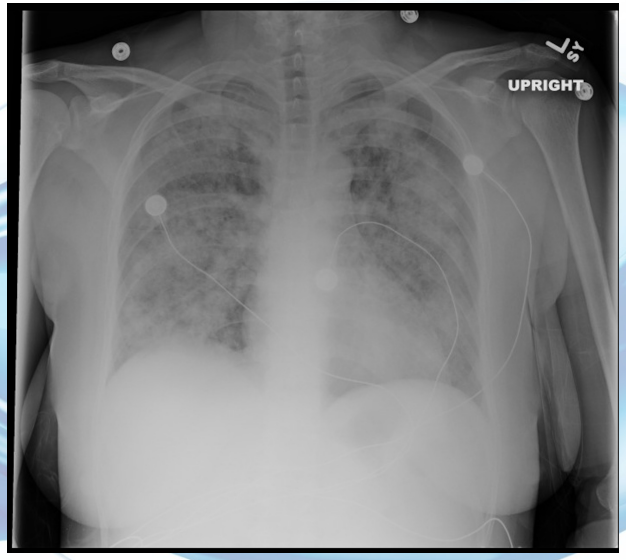
CXR looks “wet”

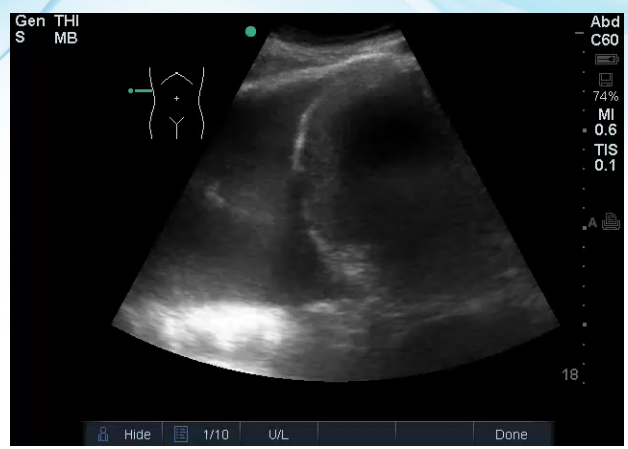


Clinical + CXR +
Lung US=
powerful combination

Hydrostatic or non-hydrostatic pulmonary oedema
VAP? US helps

Comets Pneumonia PLAPS= ARDS, not HAPE





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Kajimoto *et al. Cardiovascular Ultrasound* 2012, **10**:49
http://www.cardiovascularultrasound.com/content/10/1/49

CARDIOVASCULAR ULTRASOUND

RESEARCH Open Access

Rapid evaluation by lung-cardiac-inferior vena cava (LCI) integrated ultrasound for differentiating heart failure from pulmonary disease as the cause of acute dyspnea in the emergency setting

Katsuya Kajimoto[1*], Keiko Madeen[1], Tomoko Nakayama[2], Hiroki Tsudo[3], Tadahide Kuroda[1] and Takashi Abe[3]

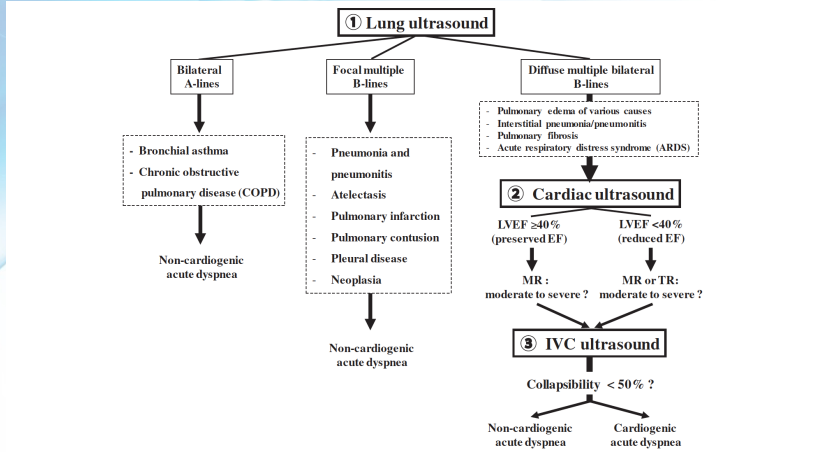

Figure 1 Algorithm for the diagnosis of acute dyspnea based on the lung-cardiac-inferior vena cava integrated ultrasound. LVEF = left ventricular ejection fraction; MR = mitral regurgitation; TR = tricuspid regurgitation; IVC = inferior vena cava.

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The duration of LCI-integrated ultrasound examination was always less than 3 minutes (Figure 1) [14]. The images

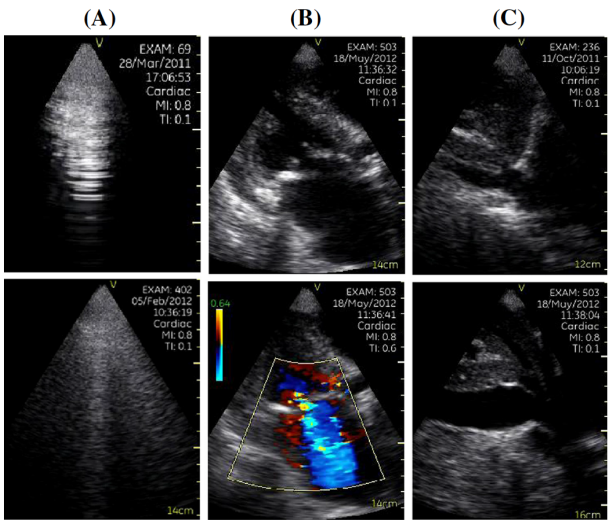


Table 2 Plasma BNP, lung ultrasound alone or combined with BNP, cardiac findings, and the LCI integrated ultrasound for diagnosis of AHFS

	Sensitivity (%)	Specificity (%)	NPV (%)	PPV (%)	Accuracy (%)
BNP ≥100 pg/ml	92.4	35.1	76.4	67.1	68.8
Framingham criteria*	79.2	56.7	65.6	64.6	70.0
Lung ultrasound alone	96.2	54.0	90.9	75.0	78.8
Both Lung ultrasound and BNP (≥100 pg/ml)	88.6	67.6	80.6	79.8	80.0
Reduced EF (LVEF <40%)	26.4	86.5	45.1	73.7	51.1
MR or TR ≥ moderate	92.4	81.0	88.2	87.5	87.7
IVC collapsibility <50%	83.0	81.1	76.9	86.3	82.2
Both preserved EF and MR ≥ moderate	56.7	100.0	61.6	100.0	67.0
Both reduced EF and either MR or TR ≥ moderate	30.1	94.5	48.6	88.9	56.7
Lung-cardiac-inferior vena cava (LCI) integrated ultrasound	94.3	91.9	91.9	94.3	93.3

* Two major or one major and two minor criteria. BNP = brain natriuretic peptide; LCI = lung-cardiac-inferior vena cava; AHFS = acute heart failure syndromes; NPV = negative predictive value; PPV = positive predictive value; LVEF = left ventricular ejection fraction; IVC = inferior vena cava; MR = mitral regurgitation; TR = tricuspid regurgitation.

Serial follow up

- Not my area chest disease
- HRCT at diagnosis
- Serial assessment
- Resource poor settings (strong level B)
- In cardiogenic pulmonary oedema semi-quantitative severity may be obtained by evaluating number of B lines… and response to therapy (strong level A)
- In critically ill 4 signs identify progression consolidation, coalesced B lines, spread out B lines, normal (strong level A)

Volpicelli G. ICM 2012;38:577- 91

PTX

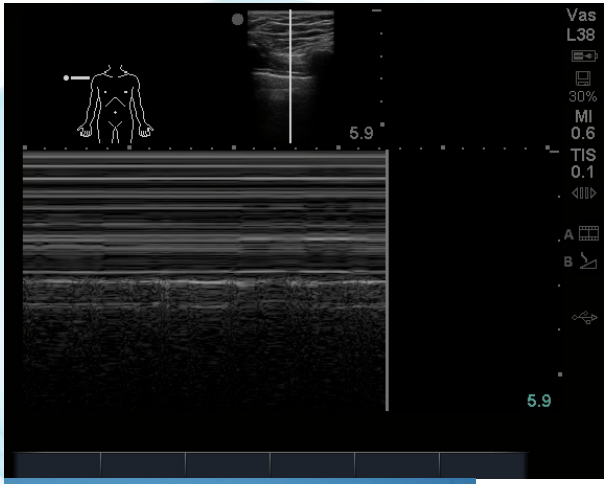
- This is tricky!
- Rule out test
- Seen more cock ups than I'd like
- Most people with reduced pleural slide have reasons other than PTX…
- … and are patients who typically might have PTX
- Still role clever use CXR and or CT

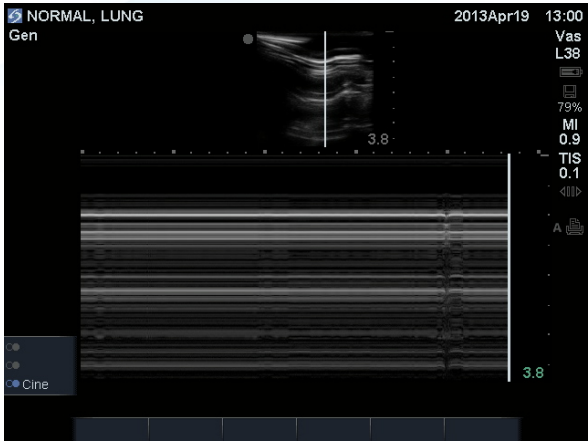
Normal

- Pleural slide
- Sparks
- A lines
- B lines
- Cardiac pulsation
- M mode seashore sign
- RULE OUT

BMUS M mode normal: the seashore

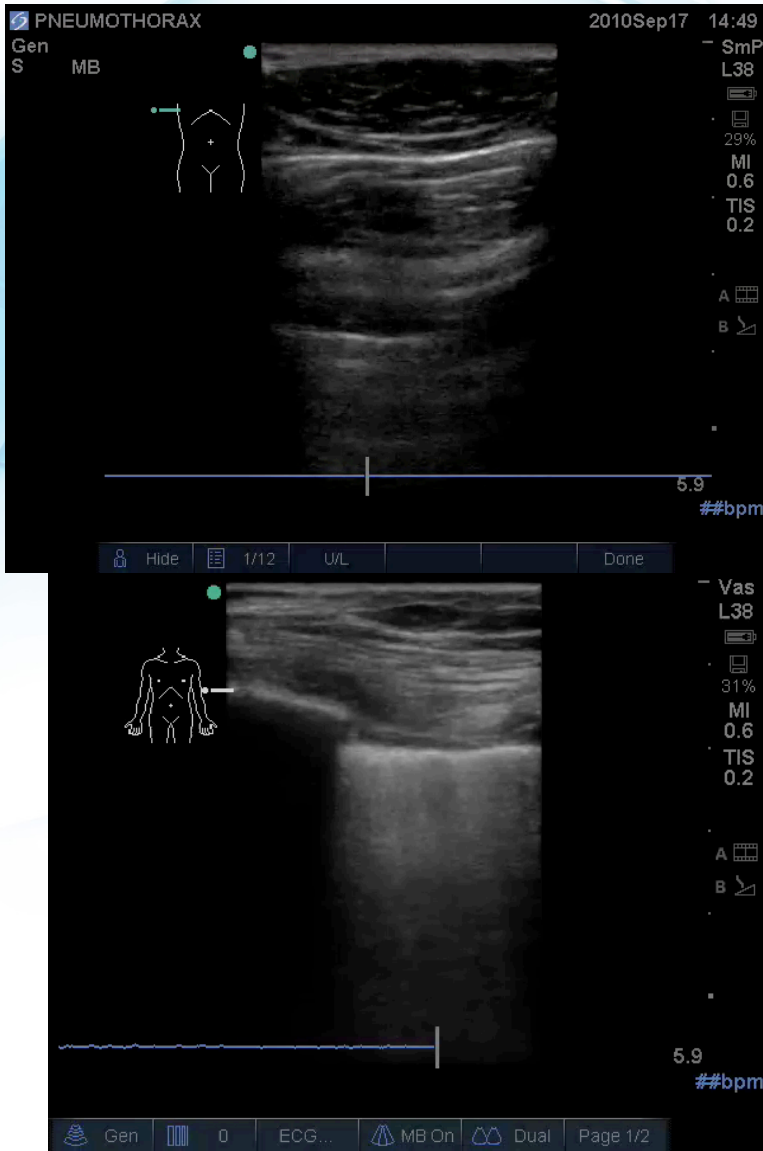
- Not a “solution”
- Visual enhancement of normal
- I much prefer 2D
- New machines ambiguous
- Everything below pleura is artifact
- Scatter



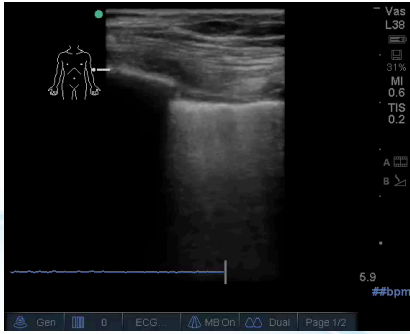


PTX

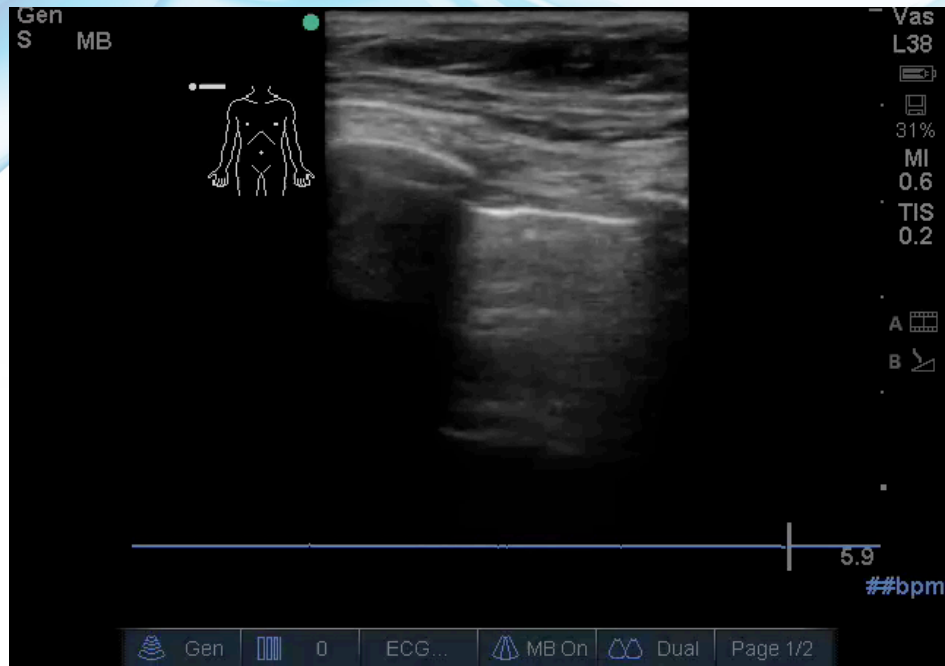
- All signs are -ve: rule out test
- No slide
- No B lines
- No pulsation
- (apart from lung point)



US and PTX

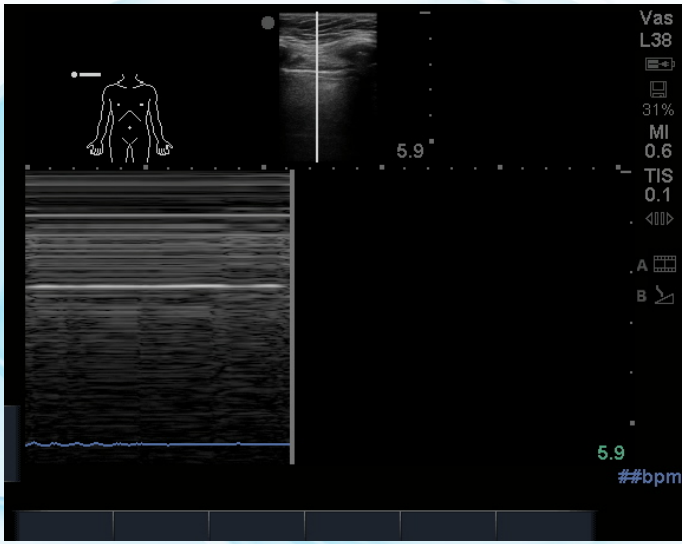


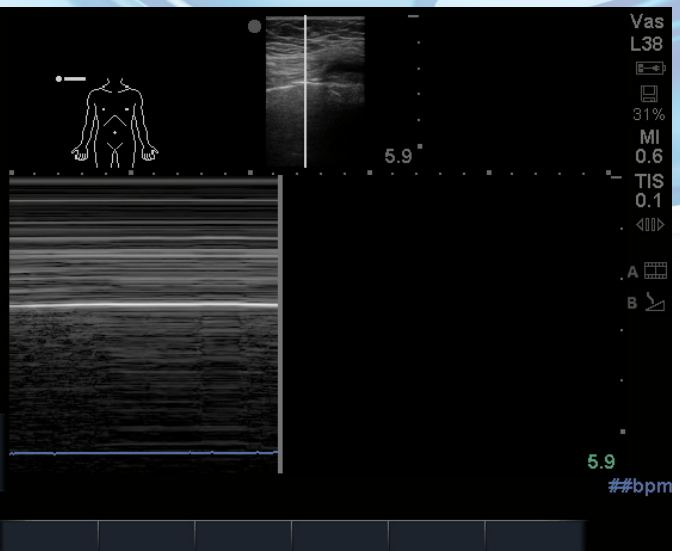
- High reflection
- Reverberation
- A lines (no B lines)



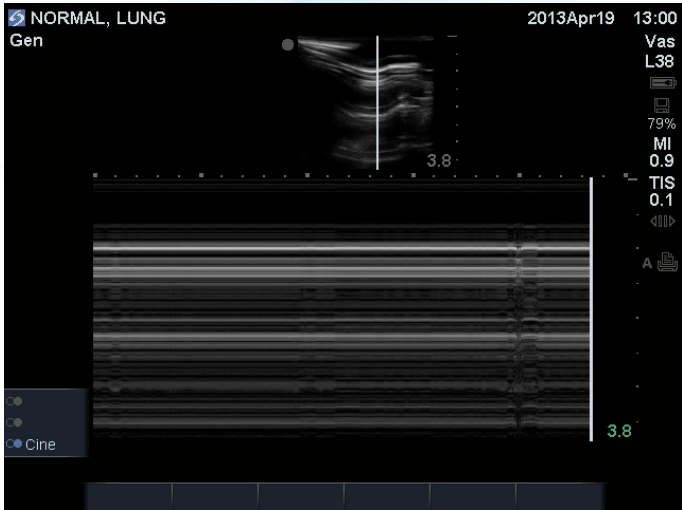
PTX and reverberation

- M-mode
- Sea
- Compare with normal





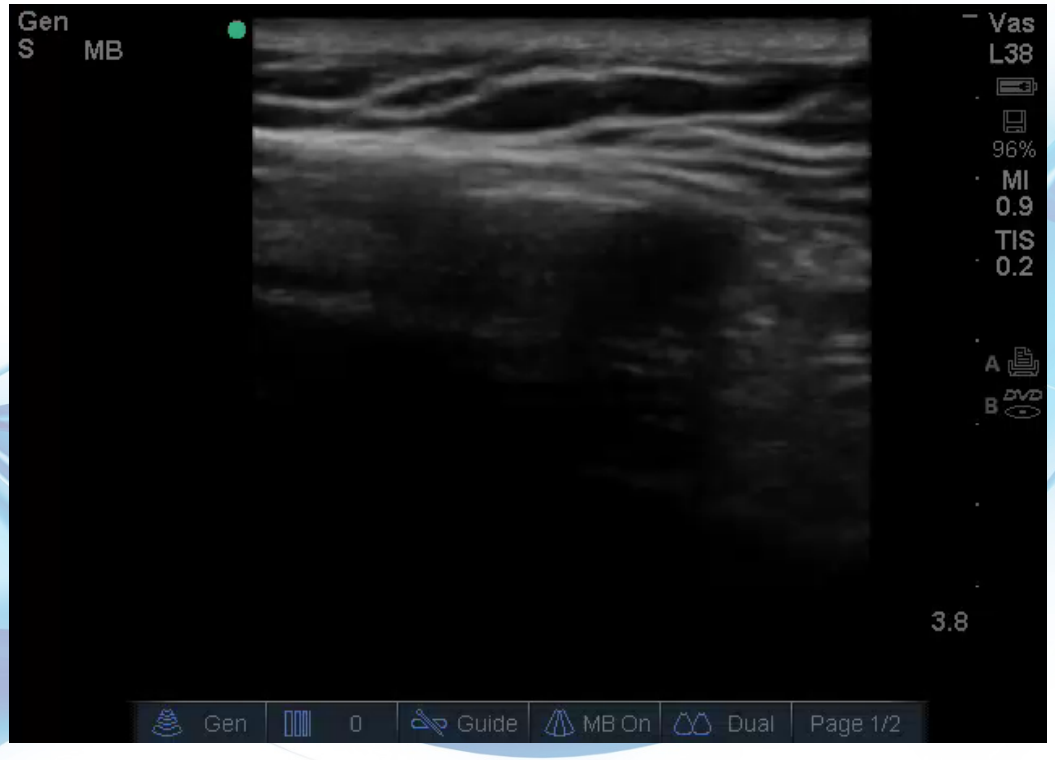
Believe me
Known PTX
Not lung point
Varies



PTX and US tips

- Use your eyes: watch and wait
- Manual ventilation
- M mode little use
- Forget power Doppler
- US often equivocal= rule out test!
- Surgical emphysema ruins everything
- Considering impact of bronchopleural fistula… the adage that there shouldn't be a CXR of a tension PTX is questionable…

Use your eyes!



Looks like pleura line
Above ribs
Chest wall tissues
Not PTX
Surgical emphysema
E line
Important as often *could* PTX

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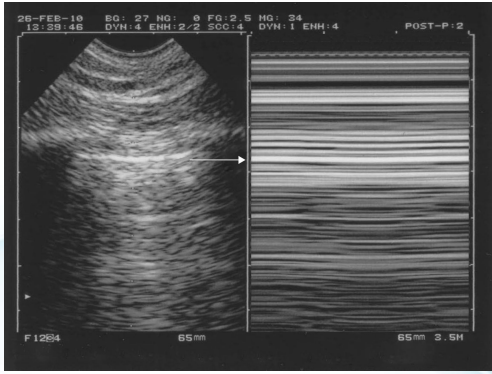
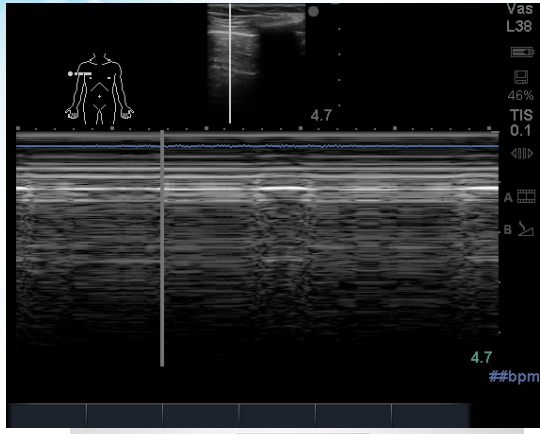
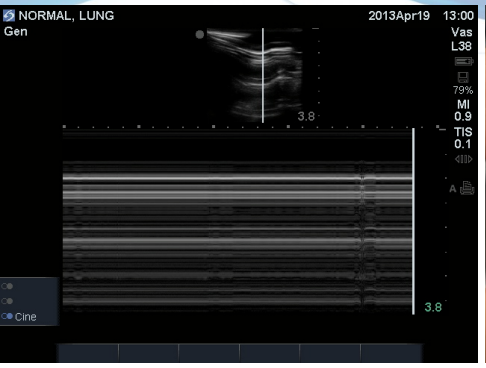
Problem “new” machines!



- Too good!
- Most PoC= departmental standard few years ago
- Lichtenstein Hitachi microconvex
- M mode ambiguous





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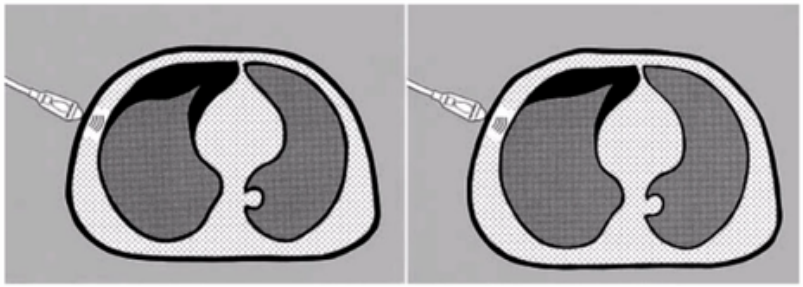
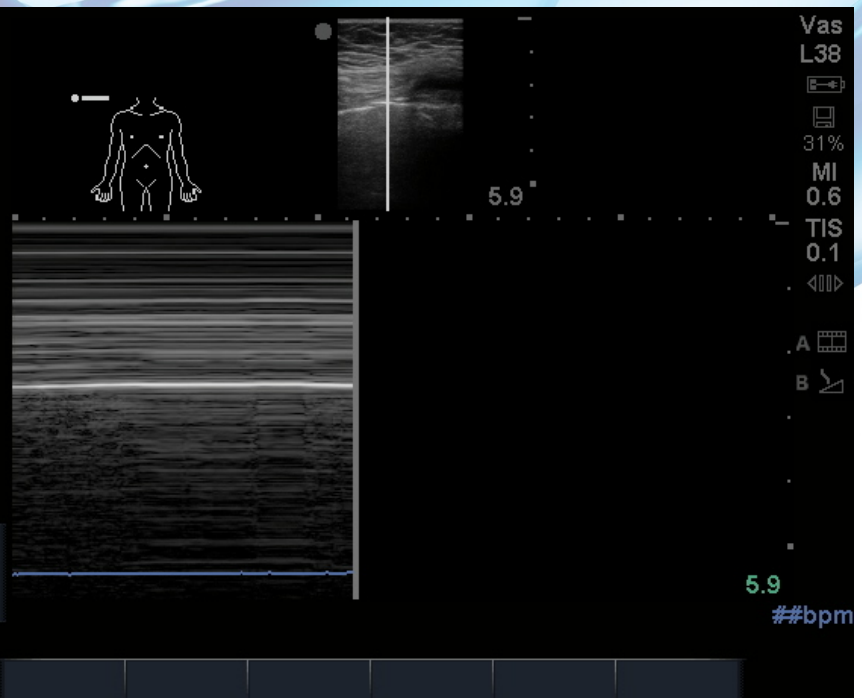
The lung point

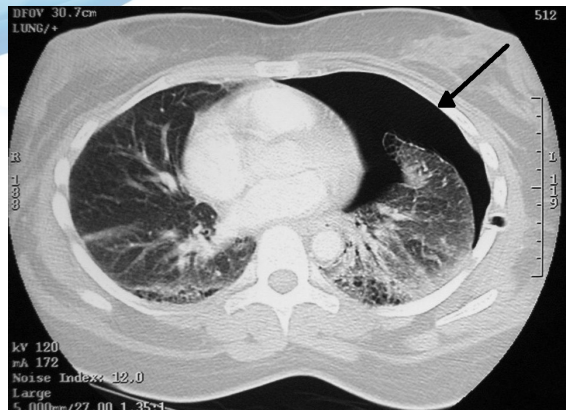
- Only +ve sign
- Lichtenstein 90%
- Me 90% don't!





Don’t know how big PTX!

- All tells you lost contact
- Might be few mm off
- Loculations/ bullae/ consolidation
- CT helps
- Best site for drain

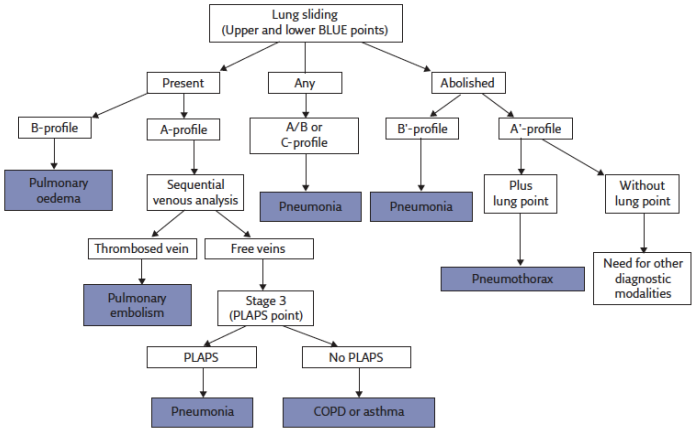


Other applications lung US

- DVT
- PE
- Weaning
- Diaphragm movement
- Shock protocols

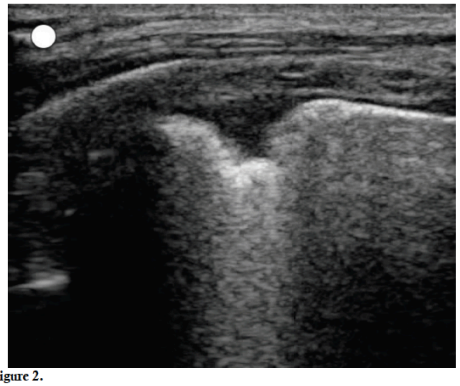
US and PE

- Not a big fan!
- Poor sensitivity
- Lichtenstein PE diagnosed leg scan…
- 80% sensitive
- CTPA here to stay
- Cardiac arrest changes pre-test probability

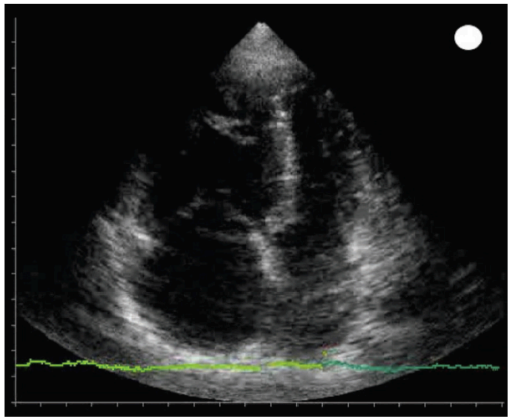


https://www.ncbi.nlm.nih.gov/pubmed/26033127

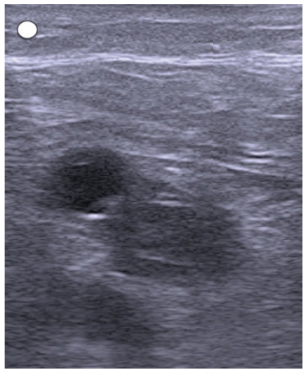
e-Figure 1.



e-Figure 2.



e-Figure 3.



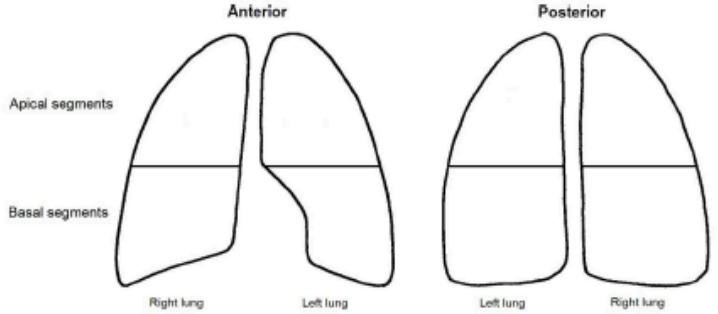
e-Figure 4. Standardized form

Patient number **Date** **Investigator**

Lung ultrasonography

Subpleural infarcts Negative Positive

Insert a Δ for each detected subpleural infarct



Heart ultrasonography Not feasible (bad acoustic window)

Right ventricular dilatation (right/left ventricular end-diastolic diameter ratio >0.9 in the apical four-chamber or in the subcostal view or right ventricular end-diastolic diameter >30 mm in the parasternal view)

	Negative	Positive
Right cavities thrombi	Negative	Positive
Pericardial effusion	Negative	Positive
Aortic dissection	Negative	Positive

Leg veins ultrasonography for deep vein thrombosis (femoral and popliteal veins)

Negative If positive: right left

Alternative US diagnosis if multi-organ US negative for PE

Pericardial effusion Aortic dissection Pleural effusion

Pneumonia Diffuse interstitial syndrome

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Test	Sensitivity	Specificity
Multi organ US	90%	86%
Lung US	61%	96%
Echo	33%	91%
Veins	53%	98%

Among the 132 patients (37%) with multiorgan ultrasonography negative for PE plus an alternative ultrasonographic diagnosis or plus a negative D-dimer result, no patients received PE as a final diagnosis.

Conclusions: **Multiorgan ultrasonography is more sensitive than single-organ ultrasonography, increases the accuracy of clinical pretest probability estimation in patients with suspected PE, and may safely reduce the MCTPA burden.**

Trial registry: **ClinicalTrials.gov; No.: NCT01635257; URL: www.clinicaltrials.gov**

CHEST 2014; 145(5):950–957

Abbreviations: MCTPA = multidetector CT pulmonary angiography; PE = pulmonary embolism

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Summary

- B line
- AIS
- HAPE vs ARDS
- PTX
- PE other applications
- Great adjunct
- Not a magic wand!

Thank you!

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