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Utilization of Ultrasound and Bioimpedance in Assessment of Dry Weight for Hemodialysis Patients

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Disclosures

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Objectives

- To describe current approaches to **dry weight** assessment
- To review the evidence for **point of care ultrasound** in volume status assessment
- To review the evidence for **bioimpedance** in volume status assessment
- To describe the practical applications of **bioimpedance** and **point of care ultrasound** for dry weight assessment in dialysis
- To review other technology that can assist in **dry weight** determination

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Poll Question 1

What is the current use of **point of care ultrasound** for **dry weight assessment** in your dialysis unit?

a) **Not available**

b) Available but **never** used

c) **Occasional** use

d) **Regular** use

e) **Integrated into workflow** in dialysis care

Results

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Poll Question 2

What is the current use of **bioimpedance** for **dry weight assessment** in your dialysis unit?

a) **Not available**
b) Available but **never** used
c) **Occasionally** use
d) **Regular** use
e) **Integrated into workflow** in dialysis care

Results

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Volume Overload in Dialysis

- Volume overload is **common** in dialysis patients
  - Studies report **20-30%** of hemodialysis (HD) patients do not achieve euvolemia even after dialysis → chronic volume overload
- Volume overload is associated with **high cardiovascular morbidity** and mortality
  - Hypertension
  - LVH and Diastolic Dysfunction
  - Sudden Cardiac Death
- Interdialytic weight gain (IDWG) of **>5-6%** of body weight is similarly associated with adverse outcomes

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Fluid removal is <u>not</u> without risk

Excessive ultrafiltration (UF) in HD is associated with:

- Intradialytic hypotension
- Myocardial stunning and other end organ ischemia
- Loss of residual renal function
- Increased mortality
- Symptoms – cramping, dizziness, nausea, vomiting
- Impacts on patient quality of life

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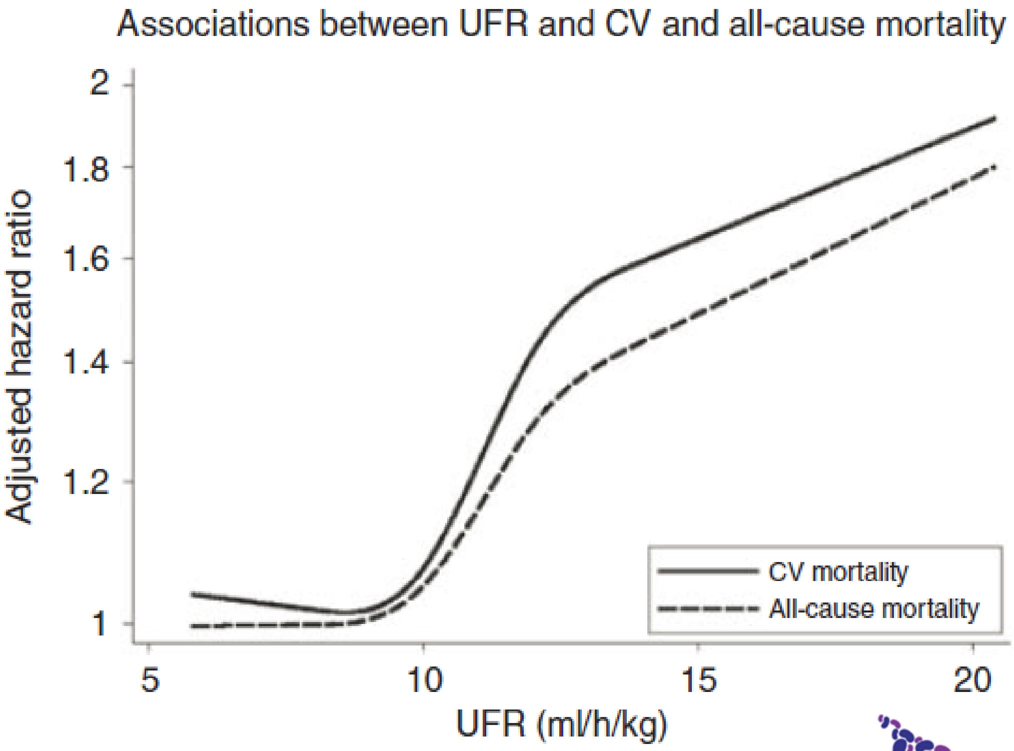
UF Rate and Adverse Outcomes

- **Higher UF rates** are associated with **higher mortality**
- Effect persists across all subgroups
- Risk increases at rates **>10ml/kg/hr** and is especially high at rates **>13ml/kg/hr**

Flythe JE et al. (KI 2011)



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What’s a dry weight?

- Defined as **lowest tolerated post dialysis weight** at which there are **minimal** signs or symptoms of hypo **or** hypervolemia
  - Many prefer term “goal weight” as implies an achievable/realistic target
  - Often involves **trial and error**
- Many have advocated for volume status to be a key marker of dialysis adequacy
  - National Quality Forum endorsed % of pts with UF rate >13 ml/kg/hr as a quality measure but not the target weight itself

There is **no gold standard** in dry weight assessment

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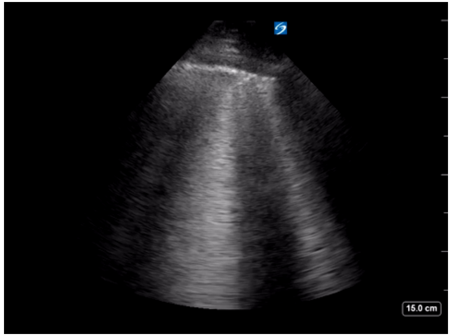
Dry Weight Assessment: Conventional Approach

- Blood Pressure
- Physical Exam
  - Edema, crackles, JVP
- Symptoms
  - Cramping, dizziness etc.
- Limitations of conventional approach
  - Inaccuracy of physical exam findings
  - Exam findings are a late finding and subclinical volume overload is common
  - Inconsistent relationship between HTN and volume overload



POINT OF CARE ULTRASOUND

Point of Care Ultrasound

Now integrated into medical education

Easy to acquire basic skills

Can use handheld or full size machines

Examination for volume assessment can be done in sitting or supine patients

Can do volume assessment in under 5 minutes

Point of Care Ultrasound (POCUS)

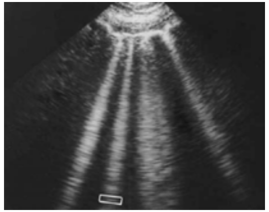
POCUS is an evolving tool for assessment of volume status in dialysis and non-dialysis patients

POCUS use in Nephrology varies based on equipment accessibility, physician training and experience

POCUS not covered today:

- Ultrasound guided CVC insertion
- Vascular access – mapping, assessment, needling
- Advanced echocardiography
- U/S of kidneys or bladder

Lung Ultrasound



- Previous thinking: Lung ultrasound is futile because of **highly refractive properties of air** → many artifacts
- In **mid-1980s Lichenstein** and others described how these ultrasound artifacts could be leveraged to identify lung pathology
  - Because interpretation is based on artifacts, it's **non anatomical**
- 2 main uses at point of care:
  1. To rule out **pneumothoraces** by examining the **pleura** → not covered today
  2. To assess lung **parenchyma** by looking for **patterns of artifacts**
     1. **A lines**
     2. **B lines**

        Focus for today
     3. Consolidation pattern
     4. Pleural effusions

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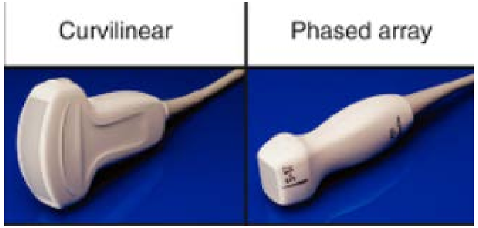
Lung Ultrasound

- Technique beyond scope of today
- Need **phased array** or **curvilinear** probe to look for A/B lines
- Lungs are examined bilaterally – standard is 4 points on each side aka BLUE protocol (Lichenstein)
- A **simplified 4 point anterior approach** has been described and is most useful in hemodialysis
- Patient can be in a **supine**, **semi recumbent** or **sitting** position
- Transducer pointed cephalad



A lines

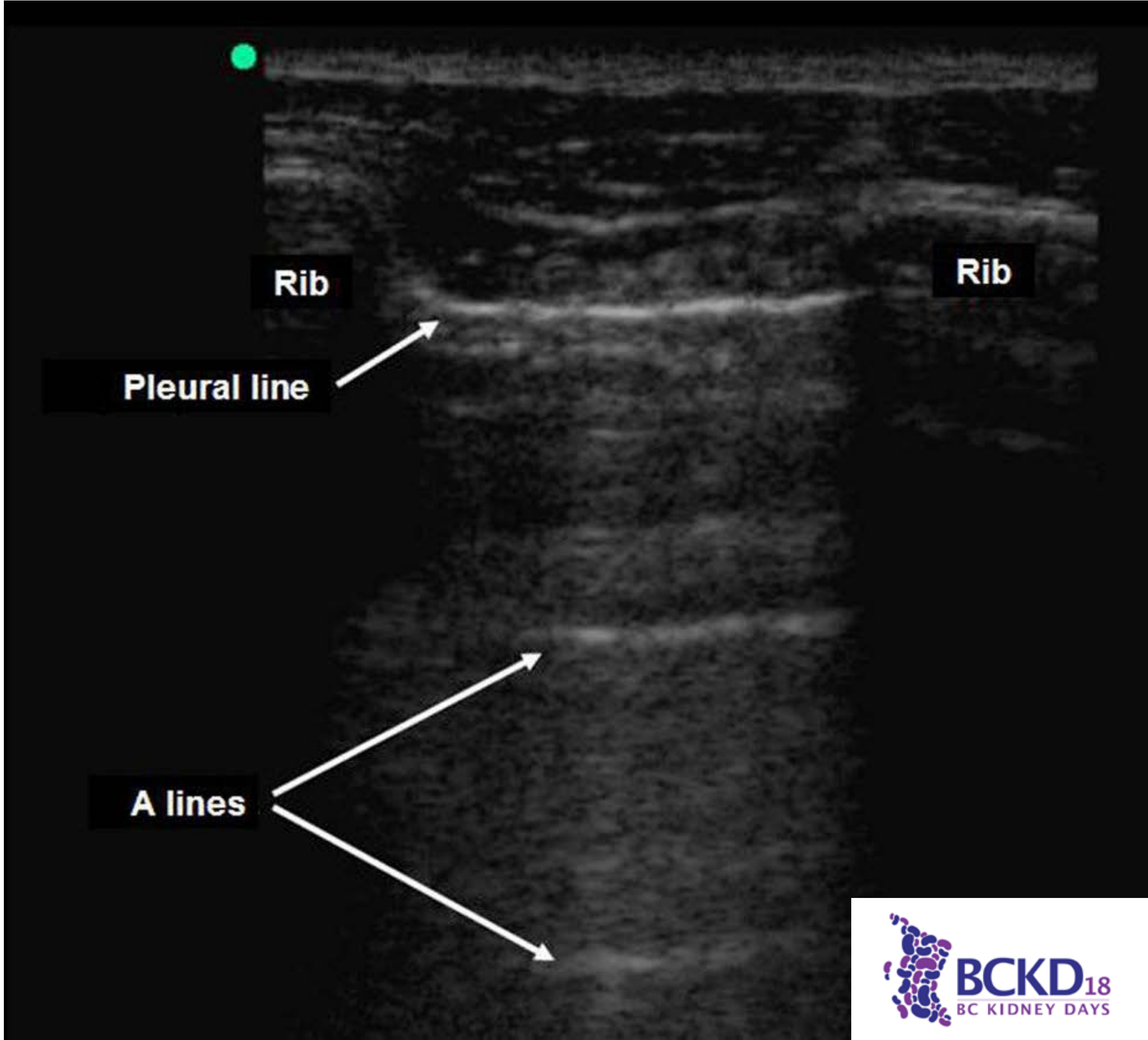
Horizontal, hyperechoic lines created by “reverberation artifact”

Multiple reflections between pleura and transducer create these **equidistant** curvilinear lines

A-line pattern throughout = normal aerated lung

Only need to see **one**

If you see A-line pattern in a dyspneic patient think non-parenchymal i.e. PE, COPD, Neuromuscular disease



B lines

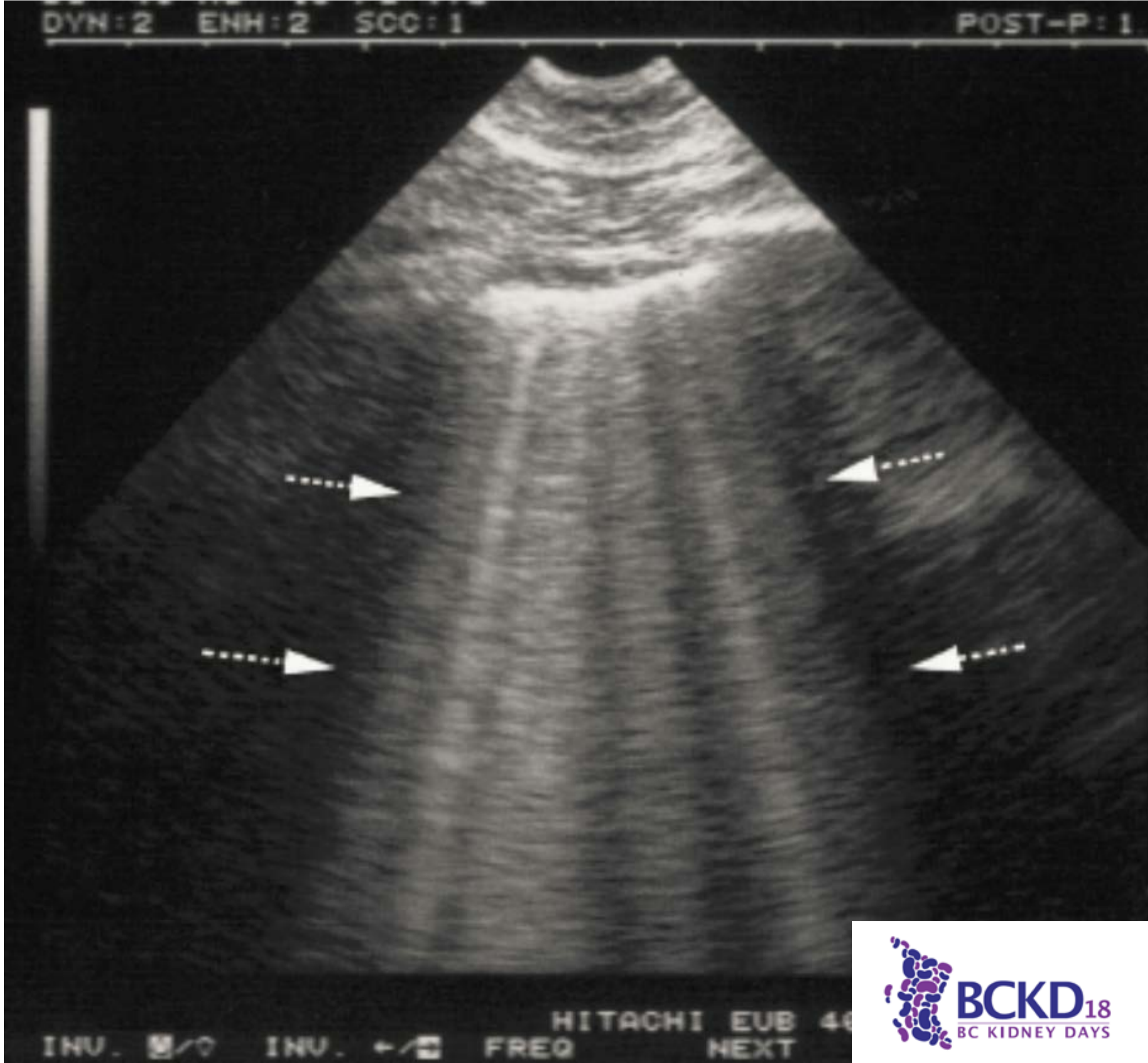
In normal lung, interlobular septa not seen but if widen due to fluid, fibrosis or consolidation, fluid can propagate causing **B line**s to form

B lines = ray-like, **hyperechoic**, **vertical** discrete lines which begin at pleural line and **extend to bottom of screen**

aka Lung **Comets** or **Rockets or Lung water**

≥3 B lines are **pathologic**

"Lung water" is a measure of volume overload, LV function and lung permeability



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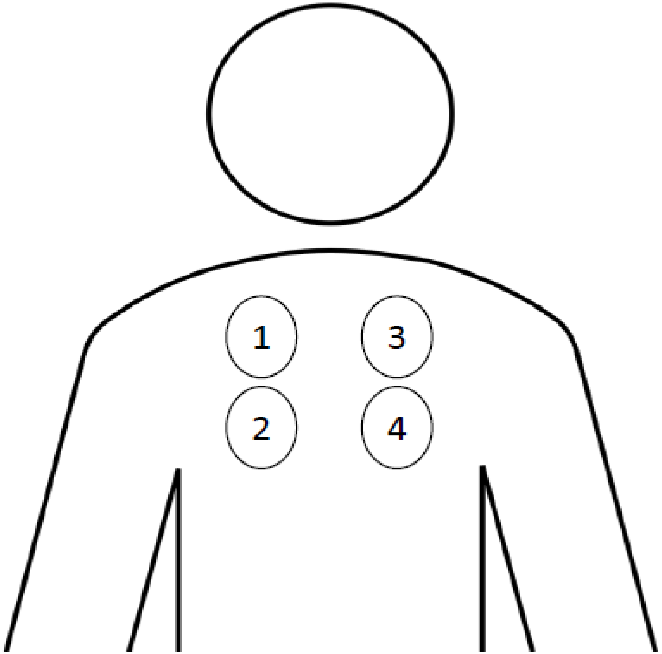
Simplified Protocol – Lung Ultrasound

- Enghard et al. (Critical Care 2015) described a simplified protocol with similar predictive value
  - L/R 3rd-4th intercostal space; L/R 6th-7th intercostal space (between parasternal and midclavicular line)
- Sum of B-lines to quantify lung water
  - Absent < 5,
  - Mild 5 to < 15
  - Mod 15 to 30
  - Severe > 30



Lung Ultrasound: Evidence

- Lung ultrasound is **more sensitive than Chest x-ray or physical exam** in detecting pulmonary edema, consolidations or pleural effusions
  - B lines can be seen in patients without symptoms of volume overload
- Lichenstein compared ultrasound findings to pulmonary pressures in 102 critical care patients with PA catheters (Chest 2009)
  - **A line pattern** highly correlated with **PA pressure < 13 mmHg** (91% PPV) and <18 mmHg (97% PPV)
- In another study, Lichenstein (Chest 2008) found that presence of **multiple B lines** anteriorly indicated **pulmonary edema** with **97% sensitivity** and **95% specificity** in 64 critical care patients

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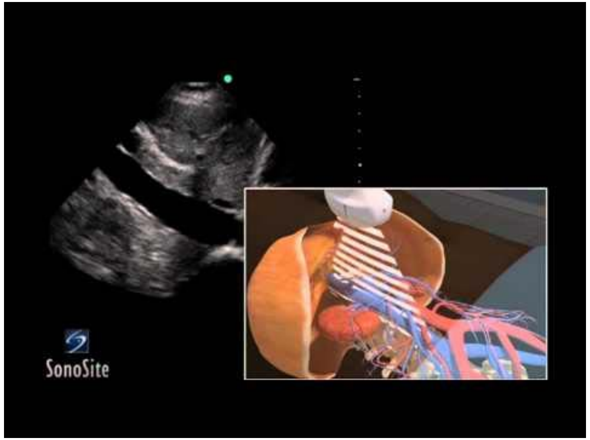
Lung Ultrasound in Dialysis

- **B lines** are associated with **elevated BNP** levels, **cardiac events** and **mortality** in HD patients
  - Dose-response relationship between number of B-lines and mortality risk: **4.2 fold risk if severe**
- Lung ultrasound is **more sensitive** than crackles on auscultation or pedal edema in HD and PD populations
- **High inter-observer reliability**
- **Similar performance to bioimpedance** in identifying overhydration and predicting cardiac mortality (Siriopol 2013/2016)
- No published data to suggest that use of lung ultrasound for dry weight assessment reduces mortality
  - *"Lung Water by Ultra-Sound Guided Treatment to Prevent Death and Cardiovascular Complications in High-Risk End Stage Renal Disease Patients with Cardiomyopathy"* (**LUST Trial**) aims to address this question in a high-risk population

Inferior Vena Cava (IVC) Ultrasound

- Obtained through a **subcostal window** of echocardiography using a **phased array** probe or alternatively a **curvilinear probe**
- **IVC collapsibility** (distensibility in ventilated) and **IVC diameter** have been studied extensively in critical care
- Measure size of IVC **2-3 cm** from the IVC/RA junction
- Indications:
  1. To guide fluid management i.e. **volume responsiveness**
  2. **CVP** estimation/approximation
  3. To rule out **cardiac tamponade** physiology
  4. **Right heart failure**



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IVC Interpretation

- **Extremes of IVC size are most helpful**
- CVP estimation (non-intubated patient)
  - IVC <2cm with >50% variation – correlates to CVP 0-5 mmHg
  - IVC <2cm with some variation (<50%) – correlates to CVP 8 mmHg
  - IVC >2cm with no variation – correlates to CVP of 10-20 mmHg
- Note: Dilated IVC also seen in cor pulmonale and severe TR

Patient	Suggest deplete	Suggest replete	Caveats:
Spontaneously Breathing	<1-1.5 cm and very collapsible (>50%)	>2cm, non collapsing	Off axis view
Ventilated, Passive breathing	>12% distensible <1.5 cm	Not distensible >2cm	Spontaneous ventilation

Caveats:

- Ability to predict volume responsiveness outside of mechanically ventilated patients is uncertain
- IVC measurements can be underestimated if view is off-axis
- IVC can be collapsed by manual pressure
- Aorta is often mistaken as the IVC
- Difficult if obese abdomen or bowel gas

IVC Ultrasound Evidence in Dialysis

- Studies in HD have demonstrated **feasibility** and **high inter-rater reliability** even with minimal training (Brennan CJASN 2006, Pazeli Nephron Extra 2014)
- **Supine** and **upright IVC correlate** well making it feasible for patients dialyzing in chairs (Panebianco AJEM 2014)
- IVC diameter **correlates well with bioimpedance** measurements (Tibia MH ASAIO J 2016)
- Studies examining its role in dry weight probing have had mixed results
  - Agarwal et al. reported sub-study of the DRIP trial (CJASN 2011) – IVC diameter was responsive to dry weight probing but its change did not predict the BP response to dry weight probing

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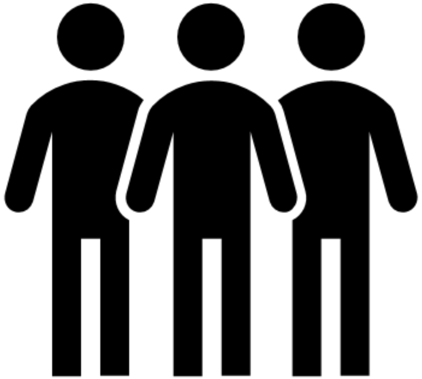
Other POCUS techniques

- JVP
  - Ultrasound of internal jugular vein (at 45˚) also correlates somewhat with CVP but appears to be less sensitive than other measures (mixed results in literature)
  - Suggest use if cannot reliably assess IVC
- Advanced echocardiography
  - LV function, Stroke Volume determination, pericardial effusions

Practical Tips

- Timing:
  - These findings are **dynamic** → consider effects of performing POCUS pre, during or post dialysis
    - Ex. Collapsible IVC during dialysis could be indicative of hypovolemia OR poor refill!
    - Can get disappearance of B lines by the end of HD
  - Most helpful to do **pre-HD** or at first part of HD run
- Successful integration into clinical practice:
  - Ensure patient privacy
  - Machine available in dialysis unit
  - Findings are documented – consider a flowsheet (continuity and medicolegal)
  - Can compare to previous findings for a given patient
    - Most machines allow you to store and label images

Which dialysis* patients might benefit from POCUS?



- Dyspneic patients
- Dialysis patients with hypo or hypertension
- Difficult dry weight assessment
- New dialysis starts

*Many uses in non-dialysis patients as well

BIOIMPEDANCE

Bioimpedance Analysis (BIA)

- Whole body **bioimpedance spectroscopy** is a technique for assessing (over)hydration and body composition using electrical (usually multifrequency) signals
- Non-invasive, painless, portable, and requires minimal training
- Place electrodes to forearm (non-fistula side) and ipsilateral ankle with patient supine
- Computer software reports analyzes inputs (+ height and weight) into two main outputs:

1. **Quantification of Fluid Status**
    - Overhydration
    - Total Body water and Extracellular Water (ECW) → Intracellular Water (ICW) calculated
2. **Assessment of Body Composition**
    - Lean tissue mass
    - Adipose tissue mass

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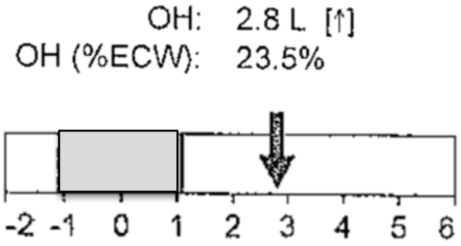
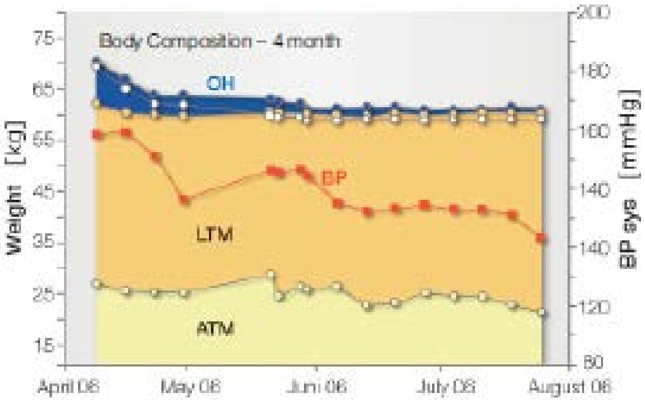
BIA Interpretation

- Multiple machines available
  - Ex. Fresenius **Body Composition Monitor** (BCM) is utilizes **multifrequency spectroscopy**
  - Reports **overhydration** status using BIA-derived ECW and ICW volumes and applying normal hydration constants for lean and fat tissue to determine excess or reduced hydration
  - Normal hydration defined as +/- 1L → **Overhydration >1L** (compared to a reference range)
  - OH/ECW index **above or below 15% is abnormal**





Fresenius BCM Guide

BIA in Dialysis: Evidence

- Observational studies have demonstrated a **higher mortality rate** in HD patients with fluid overload to ECW ratio **>15%** (BCM)
  - Studies vary on whether BIA or Lung ultrasound is a better predictor of adverse outcomes but each is an independent predictor or mortality (Siriopol 2013 and 2016)
  - Similar findings in PD population (Emma NDT 2014)
- **HD** - Hur et al. (AJKD 2013) conducted a RCT of 156 HD patients of BIA use to target dry weight (twice monthly measurement) along with echo and ambulatory BP
  - Authors observed improvements in fluid status by BIA in intervention but not control group along with regression of LV mass, left atrial volume index, blood pressure and arterial stiffness
- **PD -** Luo et al (Blood Purif 2011) RCT of 160 CAPD patients to target goal weight, reduction in hydration status and BP in the intervention
- Ongoing trials looking at residual renal function, hospitalizations, mortality

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Bioimpedance Limitations

- Only small trials available at present
- Normal reference range may less applicable to dialysis pts. (healthy ppl)
  - Unclear if reference range applies to elderly persons with sarcopenia
- Absolute Contraindications:
  - Pacemaker or defibrillator
  - Pregnancy
- Relative Contraindications:
  - Artificial joints, pins
  - Amputations
- What about PD? Does PD fluid in abdomen affect the results?
  - No significant difference! (Caron-Linert et al. PDI, 2014)

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Technique Comparison

	POCUS	Bioimpedance
Who performs it	Typically MD	RN or RD
When to perform	Anytime, preferably pre-HD	Usually prior to HD PD anytime
Time to perform	< 5 minutes	< 5 minutes
Limitations	Operator dependent	Contraindications
Additional information	Cardiac function	Body composition
Evidence in Dialysis population	Yes but need more hard endpoints	Yes but need more hard endpoints

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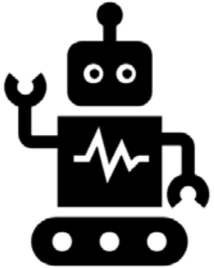

OTHER TOOLS FOR DRY WEIGHT ASSESSMENT

Relative Plasma Volume (RPV) Monitoring

- Uses optical transmission to measure **intradialytic change in hematocrit** in real time (mixed evidence)
  - **Slope** is a function of **UF rate** and **plasma refill**
  - RPV was associated with worse outcomes than usual care in CLIMB trial (Reddan et al. JASN July 2005) but many flaws in trial
  - RPV may be a useful adjunct in clinical assessment of dry weight
    - Retrospective analysis DRIP trial – flat RPV curves were helpful to predict volume overload, response to dry weight reduction and improvement in BP with dry weight reduction (Sinha et al. Hypertension 2010)
  - UF Control Biofeedback using blood volume monitoring did not change IDH, UF rates, bioimpedance measures (Leung et al. CJASN 2017)

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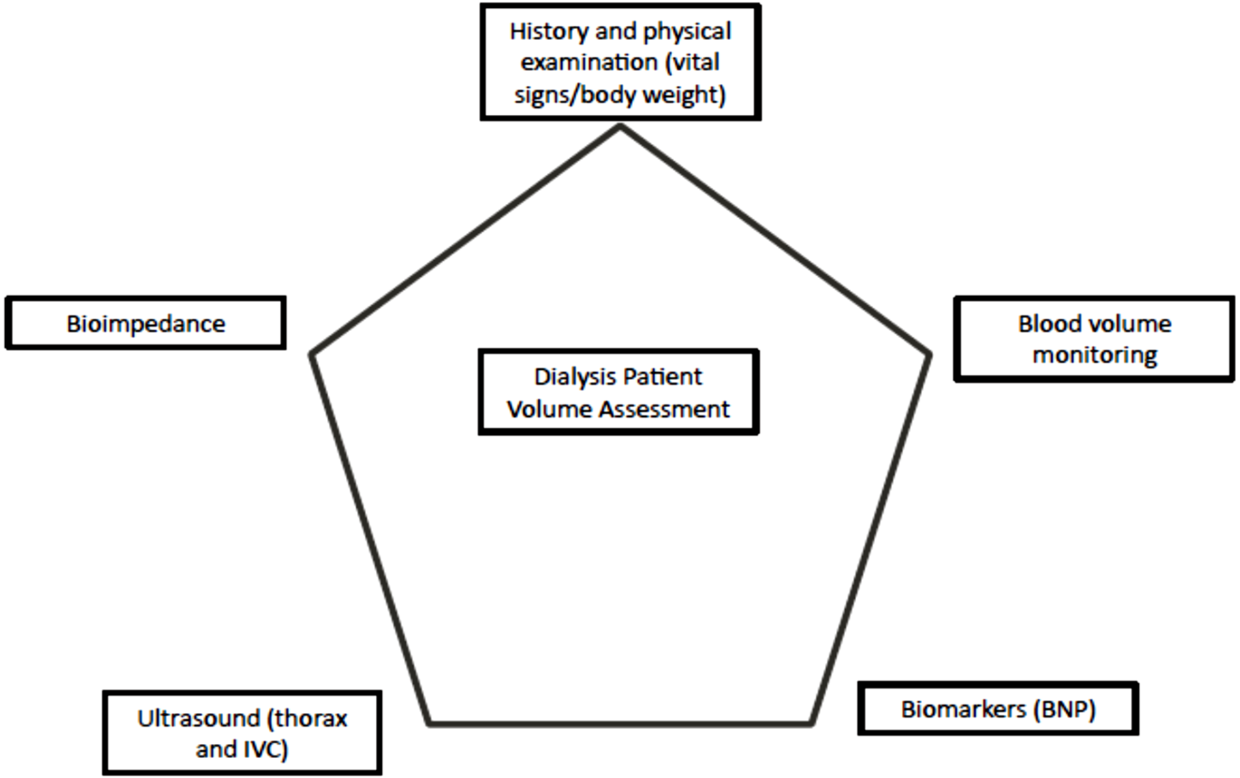
Biomarkers and Dry Weight

- Both BNP and N-terminal proBNP have been proposed as markers of volume overload in dialysis
- Known to be strong markers of cardiovascular events and mortality in dialysis patients
- Levels are also markers of LV dysfunction and LV mass which makes interpretation challenging
- Elevated levels also correlated to low BMI and malnutrition
- Levels do not appear to decline with dry weight probing (Agarwal NDT 2013)

Bottom Line: No clear role at present in dry weight assessment

Proposed approach

Rosner MH, Ronco C.
Semin Dial. 2014



Conclusions

- Volume overload is an important contributor to adverse outcomes in dialysis pts.
- POCUS and Bioimpedance are useful tools for dry-weight assessment in dialysis patients and can be complementary in practice
- Further evidence will help determine whether they improve hard endpoints
- Many courses available and techniques are easy to learn
  - Learn more about bioimpedance in the Dietician breakout session
  - Ultrasound resources to follow – ask me if you have questions!
- Remember to always **put information in clinical context**, these are just adjuncts to your clinical judgement

Resources for Education - POCUS

- CPOCUS – course and certification information
  - www.cpocus.ca
- BCPOCUS – course information, fellowships
  - www.bcpocus.ca/education
- Western Sono – video tutorials and course information
  - www.westernsono.ca
- National Kidney Foundation – yearly course at Spring meeting
  - www.kidney.org
- Textbook – Soni NJ, Arntfield R, Kory P. Point-of-Care Ultrasound, Elsevier, 2015.

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QUESTIONS?

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SUPPLEMENTAL SLIDES

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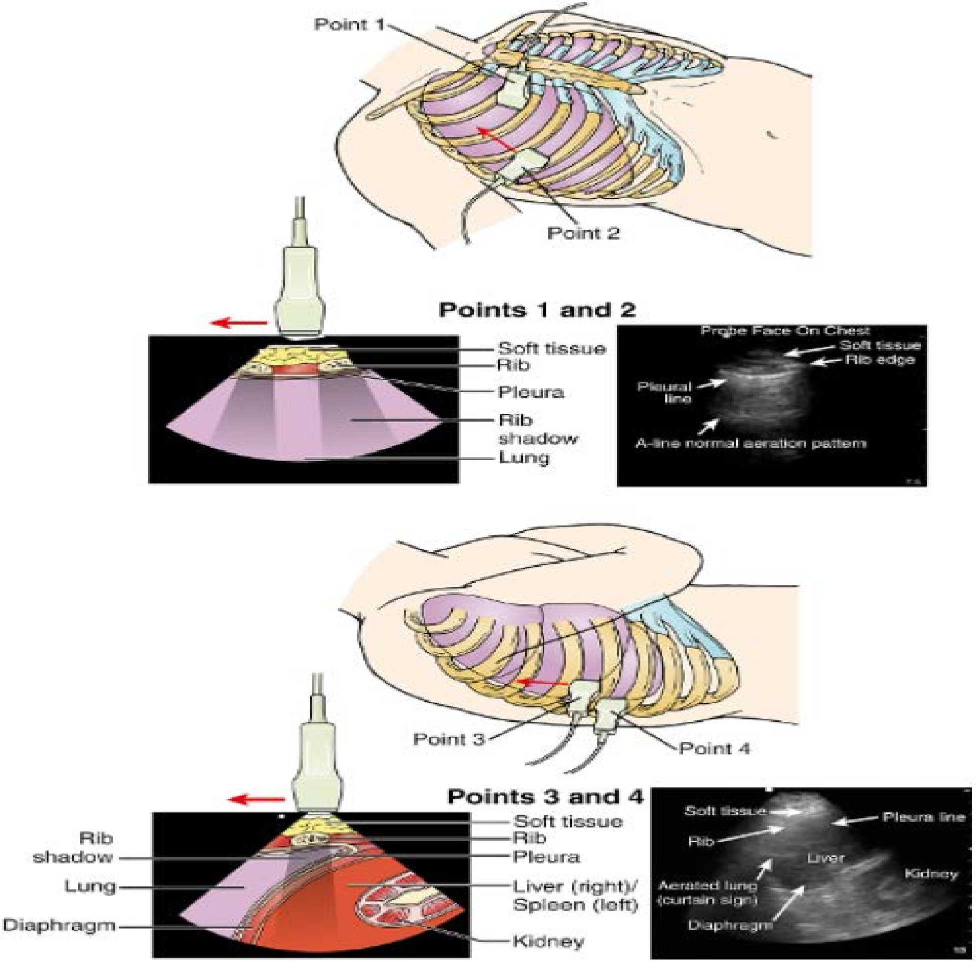
Lung Ultrasound: How-to

- Set Up:
  - **"Lung"** setting if available or **"Abdo"**
  - Depth set to least **7.5-10 cm** anteriorly and 10-15 cm laterally and posteriorly
  - Transducer marker should **point to the patients head**
    - Images displayed to the **LEFT** of the screen are **CEPHALAD**
- Probe Selection
  - Select the **phased array** or **curvilinear** probes
  - **Linear** transducer can be used to look for **lung sliding**
- Patient Positioning
  - Patient can be in a supine, semi recumbent or sitting position
  - Lungs are examined bilaterally – standard is 4 points on each side
- Note: For optimal imaging – transducer should be perpendicular to pleural surface



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