Performance and Interpretation of Sonography in the Practice of Nephrology

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2024.06.17

Outline

- Introduction
- Assessment of Cystic Kidney Diseases
- Assessment of Kidney Dysfunction
- Assessment of Chronic Kidney Disease
- Guidance for Kidney Biopsy
- Preoperative Vascular Mapping
- Evaluation of Dialysis Access for Maturity
- Assessment of Hemodialysis Vascular Access
- Volume Assessment in Patients With Kidney Disease
- Assessment of Kidney Transplant
- Conclusions

Introduction

- Utility of **point-of-care ultrasonography (POCUS)**
  - provides continuity from diagnosis to management
  - reduces fragmentation of care
  - maximizes **physician efficiency**
  - enhances patient convenience

- Applications
  - Assess volume status
  - **Guide procedures**: kidney biopsy and cannulation of dialysis access
  - **Anatomical and functional assessment** for kidneys and urinary tract.

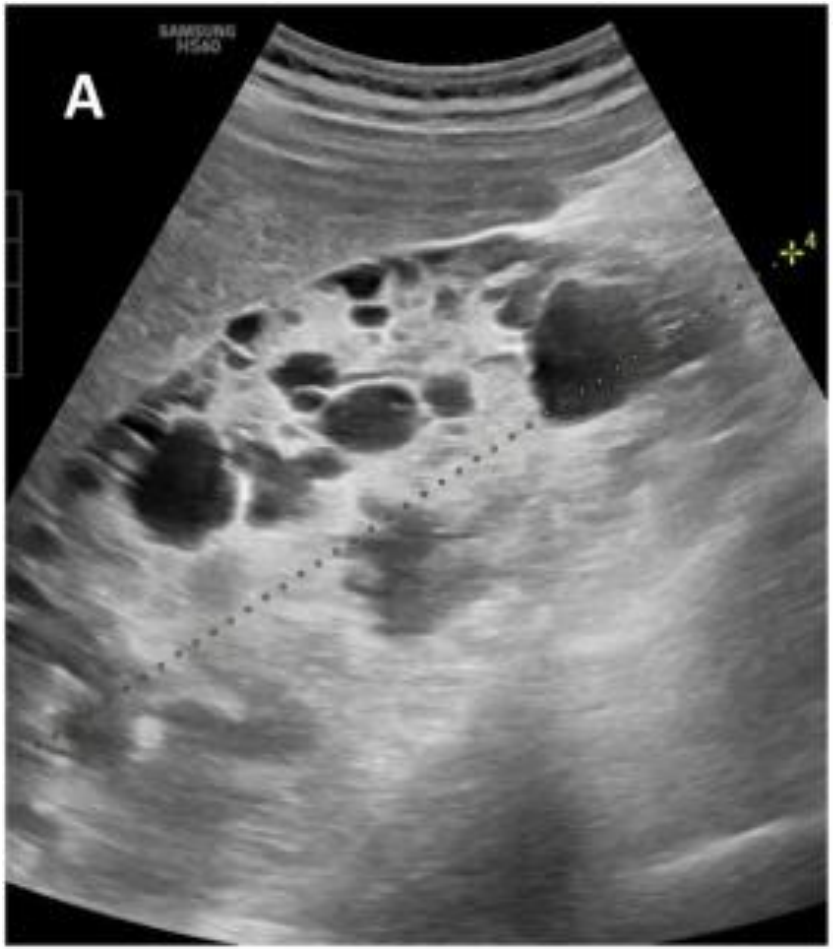
Cystic Kidney Diseases

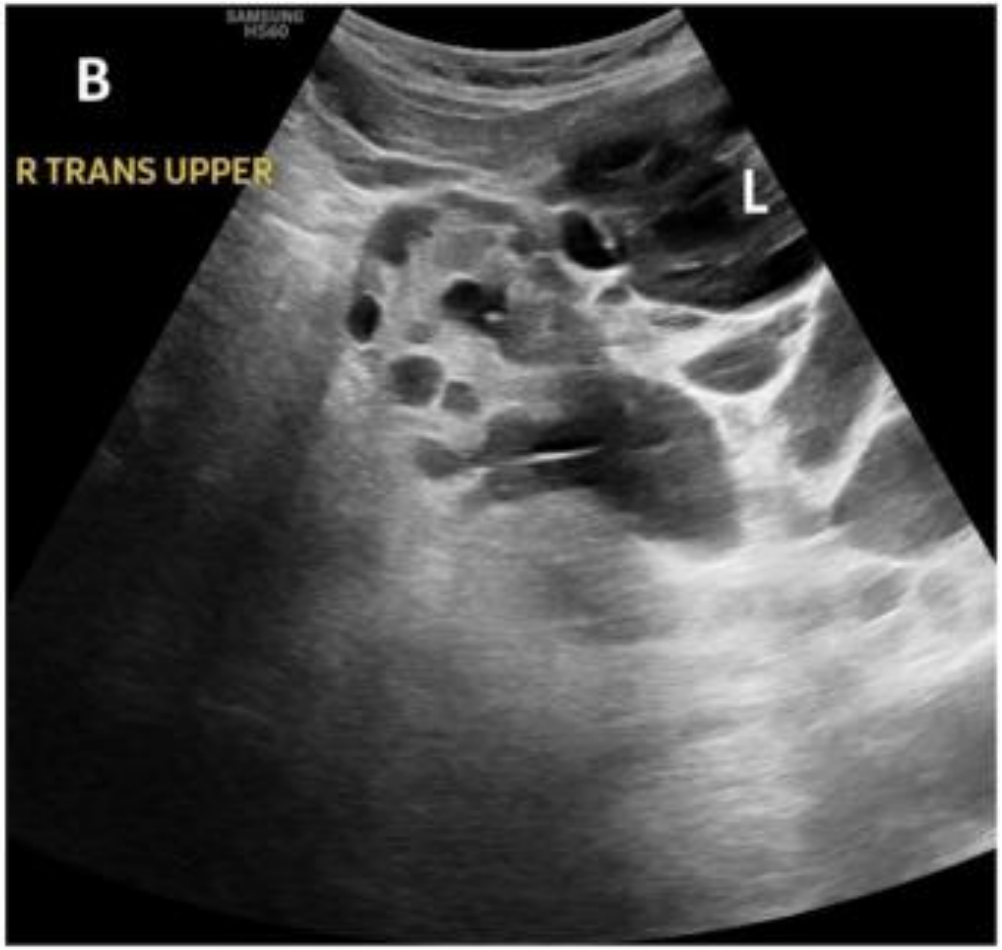
- Case 1: Autosomal dominant polycystic kidney disease (ADPKD)
- Case 2: Simple cyst and renal mass

Case 1. 42歳男性

- CC. serum creatinine of 1.8 mg/dL
- PHx: hypertension, no family history of kidney disease.
- Sonogram: bilateral enlarged kidneys (16 cm) with
- Numerous anechoic structures consistent with fluid.
- The absence of any interconnections → multicystic disorder rather than hydronephrosis.

- Question 1: Which of the following ultrasound findings is most suggestive of ADPKD?
  - (a) Kidney size
  - (b) The size of the cysts
  - (c) The distribution of the cysts
  - (d) Kidney size and the presence of liver cysts





- Right kidney length: 16 cm
- Similar of left kidney
- L: liver, also multiple cysts

Cystic Kidney Diseases

- The multiple **bilateral** cysts with renal **enlargement** → TDx: ADPKD
- DDx:
  - von Hippel-Lindau disease
  - tuberous sclerosis

- If no renal enlargement --> acquired cystic kidney disease associated with CKD.

- Unilateral disorders: multicystic dysplastic kidney

Cystic Kidney Diseases

- The kidney size in ADPKD (for prognosis): **lengths > 16 cm --> rapid progression**.

- The cysts in ADPKD
  - Almost bilateral, unilateral in mosaicism(<1%) or very early stage
  - Size range from very small to very large.
  - **Cortical** involvement (progression to destroyed kidney structure)
  - Concurrent **with hepatic cysts (rare in other cystic disorders)**

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  - (c) The distribution of the cysts
  - **(d) Kidney size and the presence of liver cysts**

Case 2. 60歳男性

- CC. evaluation of CKD
- PHx: long-standing hypertension
- Serum Cre: 1.9 mg/dL
- No urinary symptoms, hematuria, weight loss, or flank pain.
- Renal sonogram in the clinic.

- Question 2: which of the following is true?

  (a) There is a solid mass in each kidney.

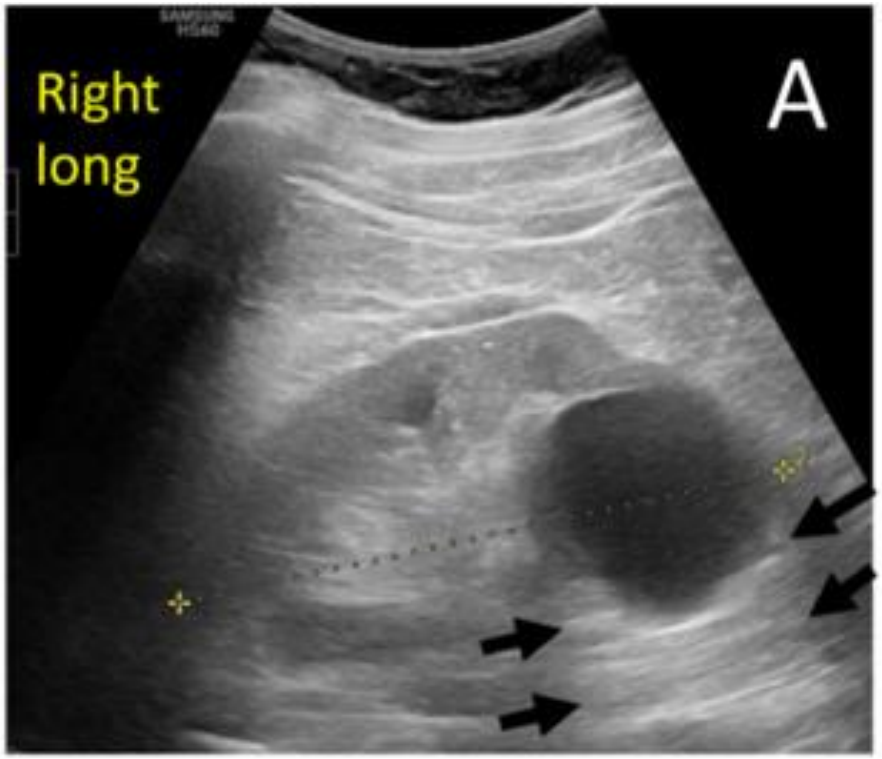
  (b) There is a simple cyst in each kidney.

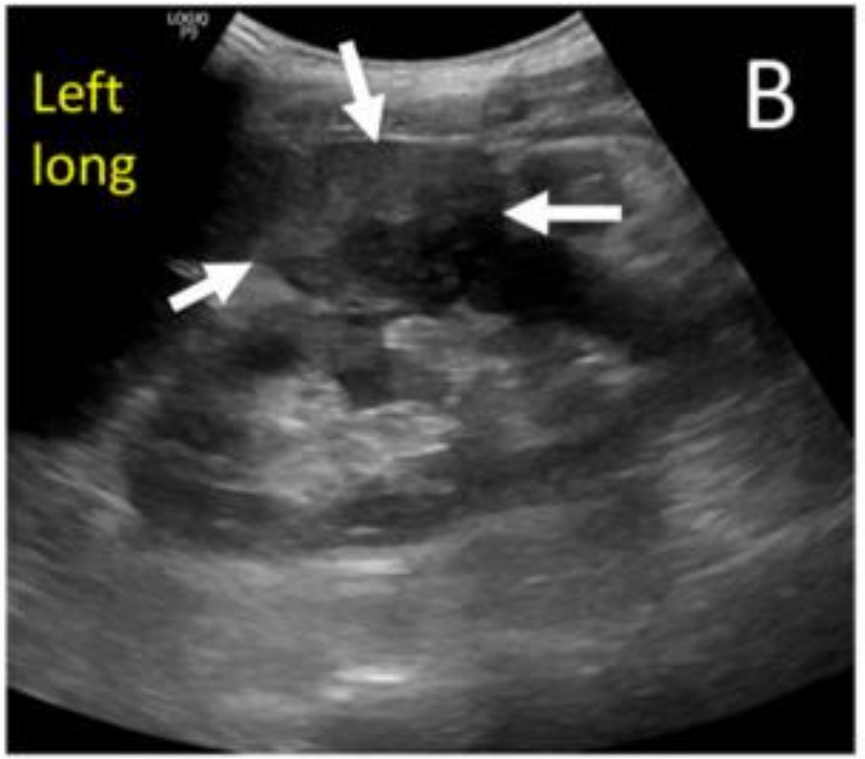
  (c) There is a simple cyst in the right kidney and a solid mass in the left kidney.

  (d) There is a complex cyst in the right kidney and a solid mass in the left kidney.

Simple cyst

Renal mass

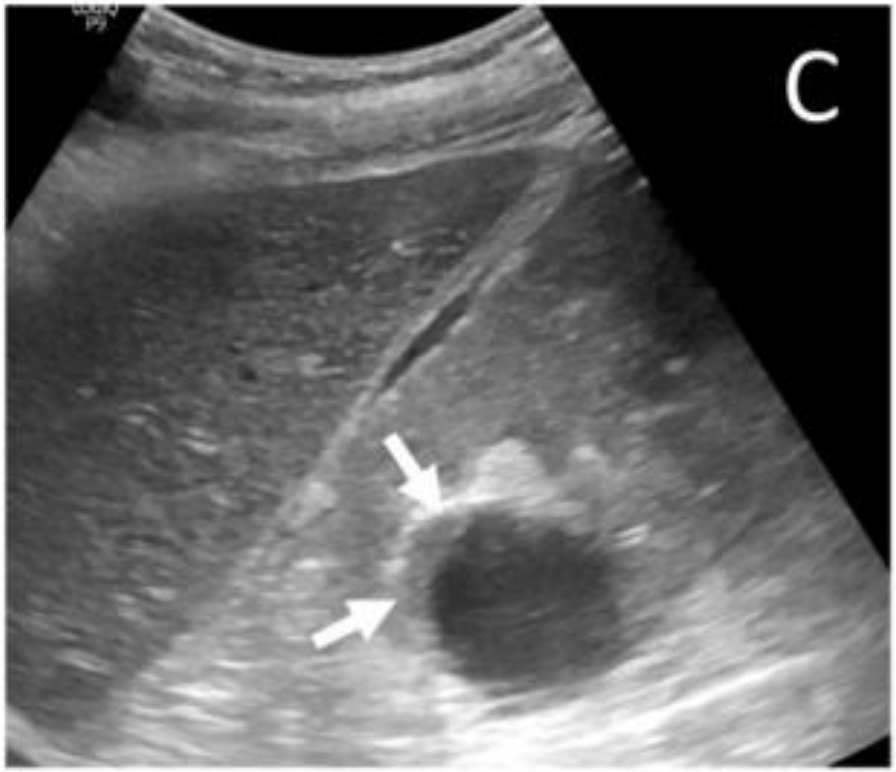


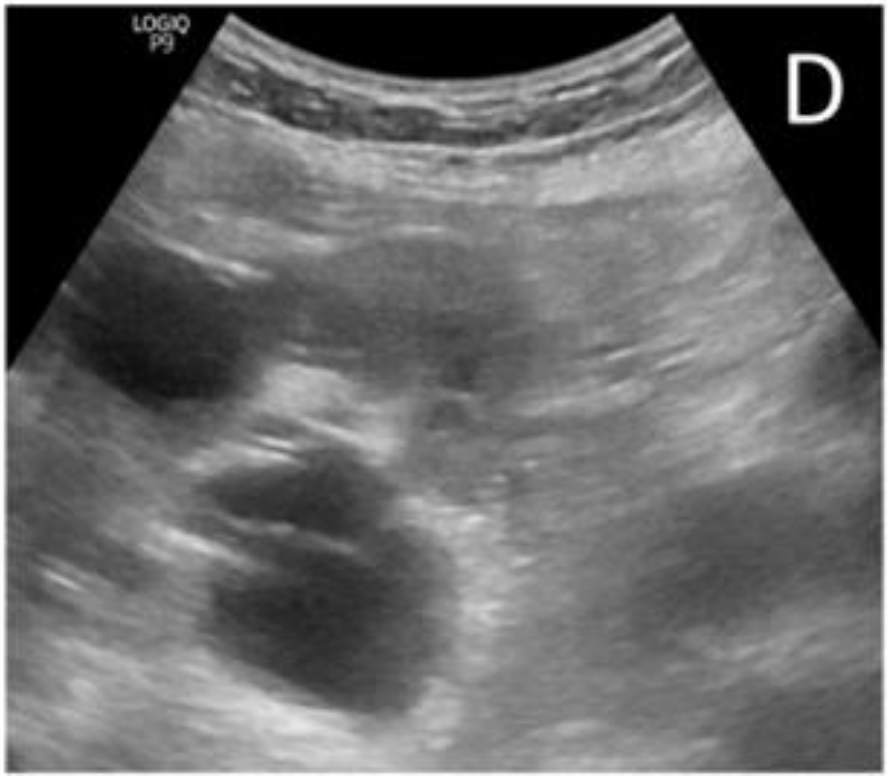


(A) Simple cyst: anechoic, homogeneous with a smooth wall and **posterior enhancement.** (black arrows)

(B) Solid mass: irregular, heterogeneous echogenicity, no post. enhancement.

不同病人的比較: 複雜囊腫





(C) Irregularities in the cyst wall.

(D) Complex cyst with thick septations and internal echoes

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Kidney Dysfunction

- Case 3: 75歳男性

- AKI assessment : post-renal etiology, urinary tract evaluation

Case 3. 75歳男性

- CC: for AKI assessment
- Serum Cre 1.5 mg/dL. (normal range 9 months ago,)
- No HTN, DM history
- Denied hesitancy, flank pain, or dysuria.
- PE: peripheral edema.
- Sonogram: right kidney hydronephrosis and left kidney grossly normal.

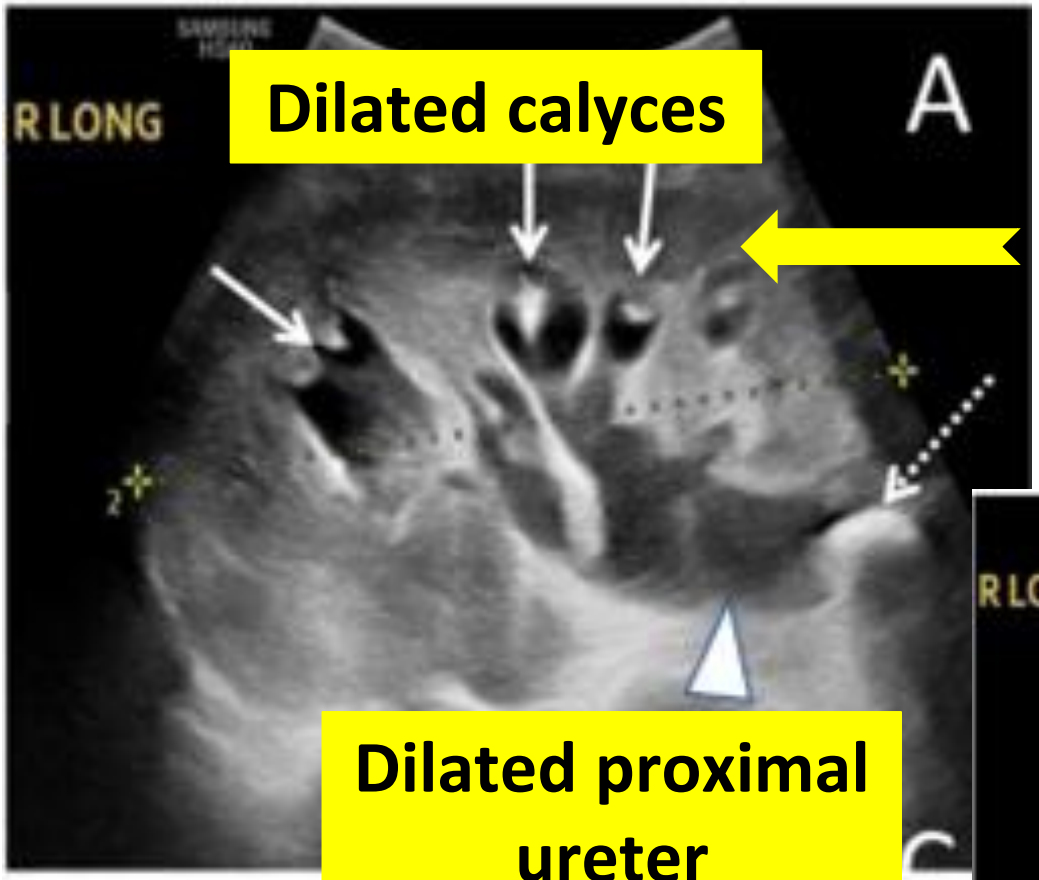
- Question 3: Which of the following statements is true?

  (a) The hydronephrosis is chronic.

  (b) There is obstruction of the proximal ureter.

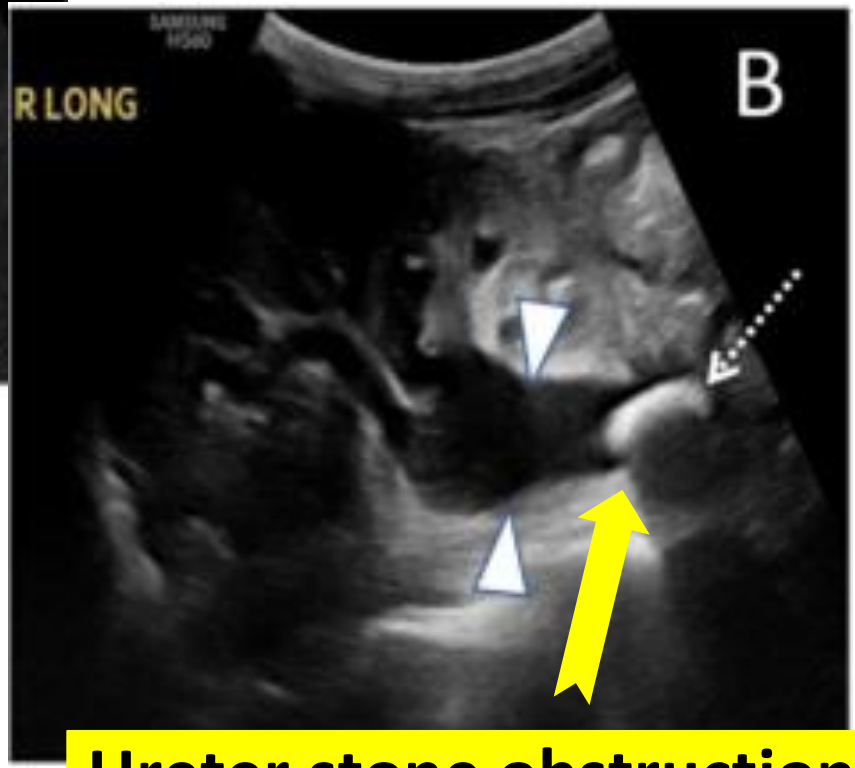
  (c) The cause of the hydronephrosis is not apparent from these images.

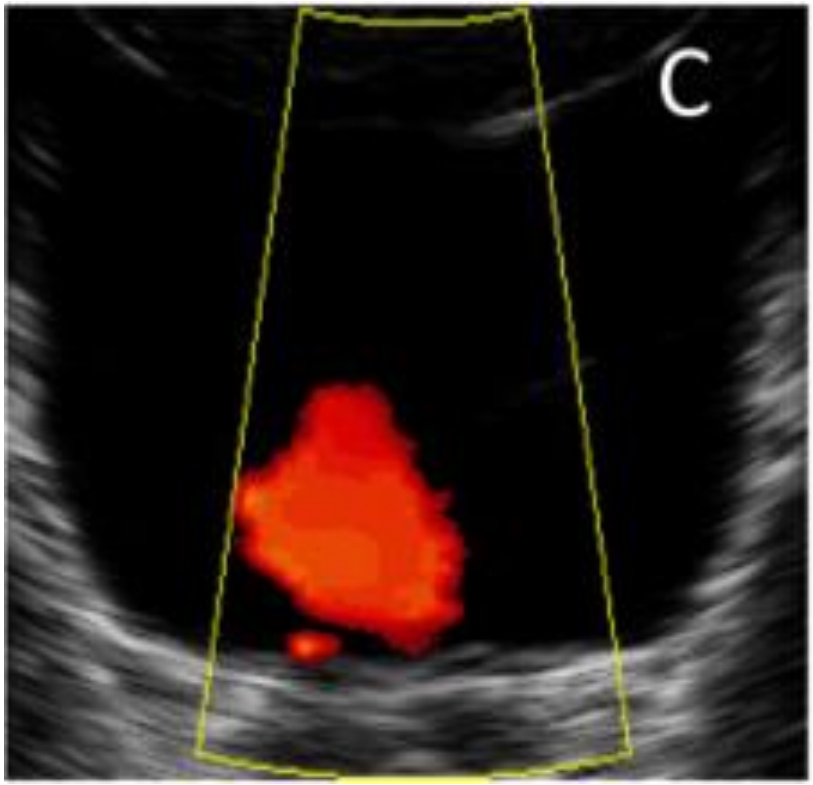
  (d) Examination of the bladder is not required in unilateral obstruction.



- Significant amount of tissue between the minor calyces and the kidney border

--> **no atrophy or chronicity**





- Transverse image of the bladder with color Doppler: only left ureteral jets observed (right ureter obstruction)

- **Ureteral jets**: pulses of urine traveling down the ureter **(no obstruction)**

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Chronic Kidney Disease

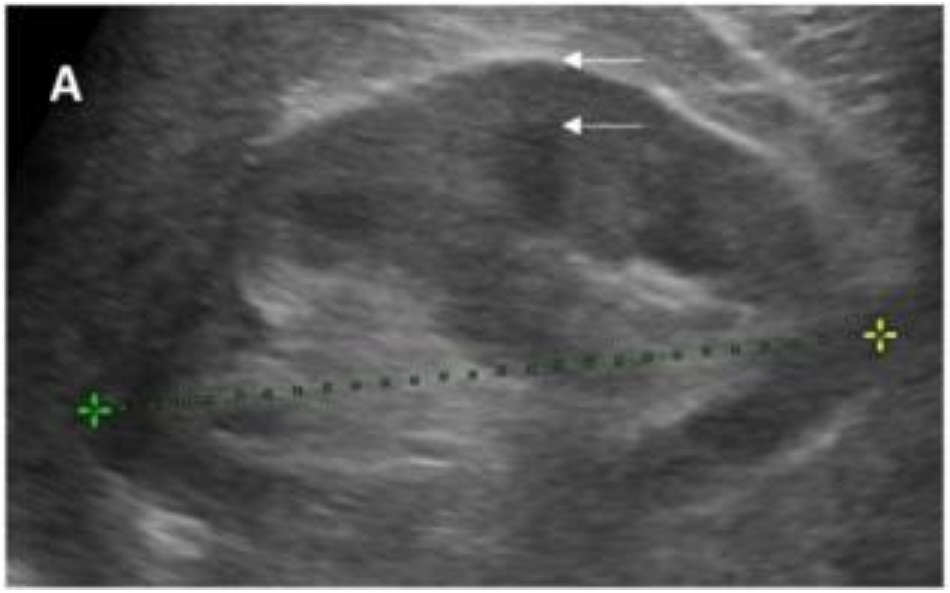
- Case 4: 54歳女性

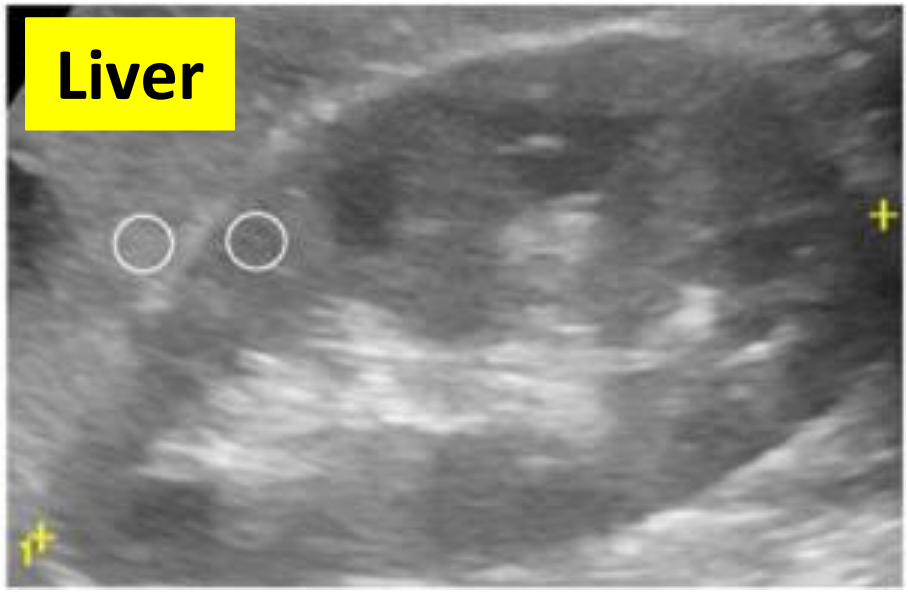
- CKD assessment : measurement of cortical thickness and echogenicity

Case 4. 54歳女性

- CC. hematuria and proteinuria
- Serum Cre: 2.1 mg/dL (normal range several years ago)
- PHx: well-controlled hypertension.
- Family history: her mother had CKD.
- Renal sonogram: normal cortical echogenicity, right kidney length: 9.2 cm and left kidney length: 9.5 cm.

- Question 4: What parameter is the most specific for assessing the presence of advanced CKD?
  - (a) Kidney length
  - (b) Cortical thickness
  - (c) Cortical echogenicity
  - (d) Doppler measurement of resistive index

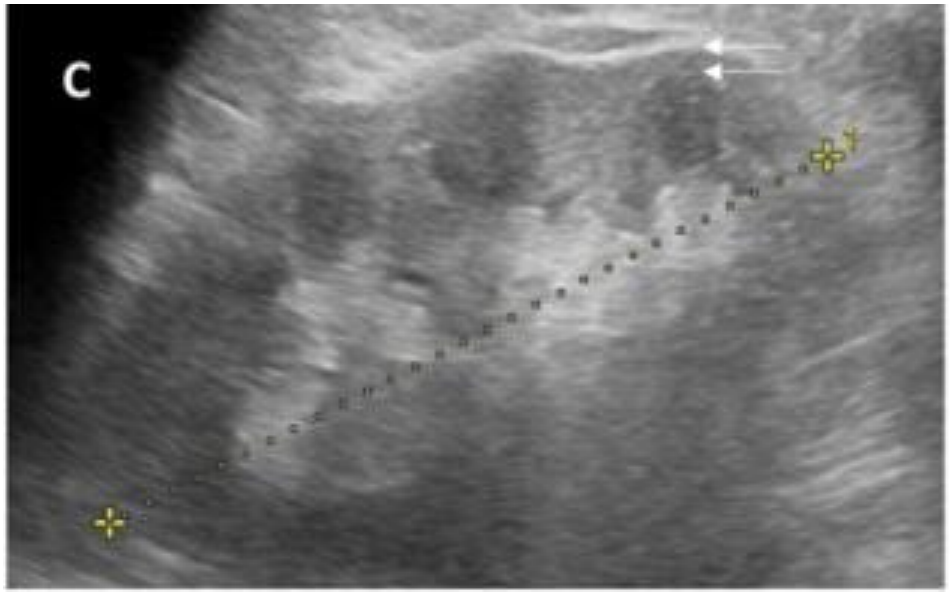


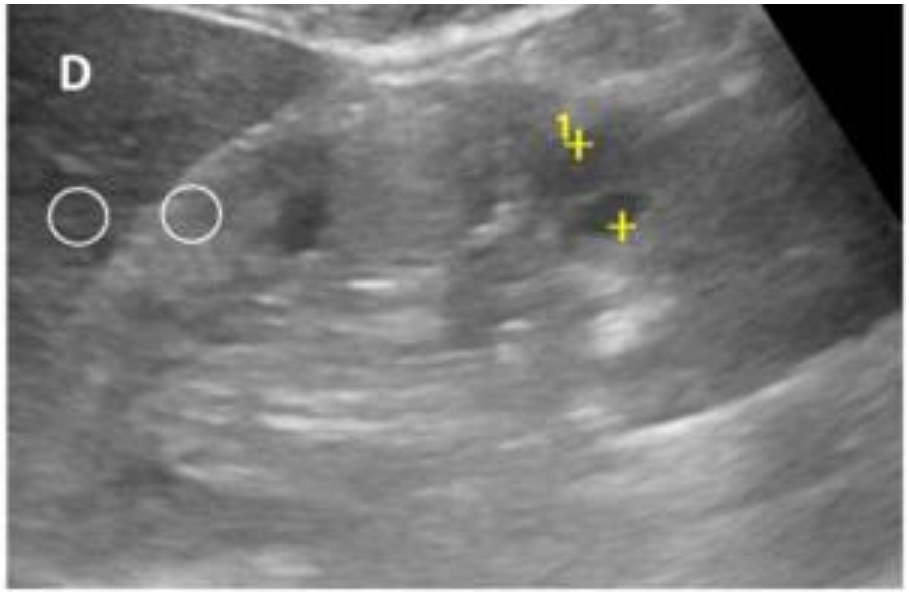


- The cortical thickness: from the base of a pyramid to the edge of the kidney (arrows): 8 mm

- The cortical echogenicity: less than that of the liver at the same depth (circles).

不同病人的比較: 皮質厚度





(C) Cortical thinning (3 mm) → 切片可能找不到可治療原因

(D) Increased cortical echogenicity with the normal cortical thickness.

Chronic Kidney Disease

- Kidney size: small (**length** usually < **10 cm** in average) → low sensitivity and specificity.
  - Repeat the measurements at least 3 times
  - Width and depth: inaccurate, useless
  - Vary with body size --> **lean body mass**, adjusted to body height
  - **Larger in men** independent of body size.

- **Cortical thickness**: < **normal 0.7-0.9 cm, specific to CKD.**

Chronic Kidney Disease

- Echogenicity of cortex: less than liver or spleen at the same depth
  - CKD may increased (fibrosis) or normal
  - **DDx: AKI also increased echogenicity**
  - Prominence of the medullary pyramids.

- **Resistive index**: extrarenal factors, **useless** in renal sonography.

同場
加映

Renal resistive index (RI)

- A sonographic index of **intrarenal arteries**
- = (peak systolic velocity - end-diastolic velocity) / peak systolic velocity
- The **normal range: 0.5 - 0.7**
- **Elevated** values → **poor prognosis**
- Measure: use spectral Doppler
  - arcuate arteries (corticomedullary junction)
  - interlobar arteries (near to medullary pyramids)
- **Reflect central hemodynamic (cardiac or aortic)** characteristics rather than kidney function itself.

Ref. https://radiopaedia.org/articles/renal-arterial-resistive-index

同場
加映

Differential diagnosis of RI

- Elevated values
  - **ureteric obstruction**
  - extreme hypotension
  - very young children
  - perinephric fluid collection
  - abdominal compartment syndrome

- Elevated values in a **transplant kidney**
  - acute tubular necrosis (ATN)
  - acute or chronic transplant rejection
  - **renal vein thrombosis**
  - drug toxicity
  - ureteric obstruction
  - perinephric fluid collection

- **Decreased values: renal artery stenosis**

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Case 4. 54歳女性

- continued: A renal biopsy was considered in order to make a histologic diagnosis.

- Question 5: Which of the following is true regarding kidney biopsy in this patient?

  (a) The kidney size in this patient precludes a kidney biopsy.

  (b) A computed tomography (CT)–directed biopsy would be safer than an ultrasound-guided biopsy.

  (c) The biopsy needle may be poorly visualized by ultrasound.

  (d) Real-time imaging is required for this ultrasound-guided biopsy.

Guidance for Kidney Biopsy

- Her kidneys size is within the normal range for a woman of her body size, and the cortical thickness is as expected → indicated to biopsy

- Published data
  - 成功率和併發症比率: ultrasound ~= CT
  - ultrasound guided **performed by nephrologist**: 成功率、併發症比率、切片腎絲球數目 **>= CT guided or 其他科醫師執行**

- **Needles** are specular reflectors that direct most of the sound away from the probe when insonated at an angle --> **not well detected**.

- The renal biopsy diagnosis: IgA nephropathy.

Case 4. 54歳女性

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Preoperative Vascular Mapping

- Case 5: Vascular diameters measurement for arteriovenous fistula (AVF) construction

Case 5. ESRD 準備透析要做血管

- She is wait-listed for a transplant and undergoning in-center hemodialysis.
- Preoperative vascular mapping via ultrasound
- Vascular diameters on her nondominant arm
  - radial a.: 2.2 mm; ulnar a.: 2.0 mm; proximal radial a.: 4.2 mm; brachial a.: 5.2 mm
  - cephalic v. at wrist: 2.6 mm; perforating v. in forearm: 3.1 mm; cephalic v. at elbow: 3.3 mm; and basilic v. at elbow: 4.9 mm
  - The veins are patent and compressible.

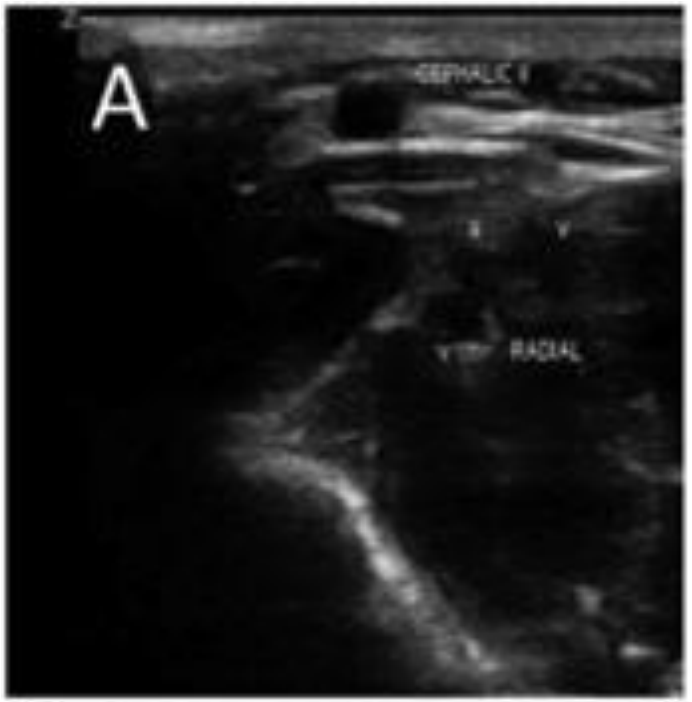
- Question 6: Which of the following statements is correct to the first choice of access?

  (a) A surgical radiocephalic arteriovenous fistula (AVF) in the distal wrist

  (b) A percutaneous proximal radial artery AVF in the upper forearm

  (c) A brachiocephalic AVF in the upper arm

  (d) She does not have veins suitable for an AVF, and an arteriovenous graft should be the first choice of access.



- Radial artery: 2.2 mm
- Cephalic vein at wrist: 2.6 mm
- Proximal radial artery (PRA): 4.2 mm
- Perforating vein (PV): 3.1 mm

- Cephalic vein at elbow: 3.3 mm

- Basilic vein at elbow: 4.9 mm

Preoperative Vascular Mapping

- Ultrasound evaluation vs. venograms: non-invasive, no contrast or radiation exposure
- KDOQI guidelines: preoperative vascular mapping for those patients who are at high risk for AV access failure
- High risk for **AV access failure**
  - morbid obesity
  - older age
  - **women**
  - peripheral vascular disease/ vessel damage
  - coronary artery disease
  - **central venous stenosis**

Preoperative Vascular Mapping

- Assessment of the vasculature: **B-mode**
- Candidate to physiologically mature fistula
  - **A**rterial diameter **>= 2.0** mm
  - **V**enous diameter **>= 2.5** mm
- Proximal radial artery and the perforator vein
  - diameter >= 2 mm
  - **distance <= 1.5 mm**
- The **first access of choice**: the most distal site, **radiocephalic or snuffbox fistula**

Case 5. CKD to ESRD 準備透析

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Evaluation of Dialysis Access

- Case 5 : maturity (做完瘻管了可以用嗎)
- Case 6 : troubleshooting (瘻管用久快壞了)

Case 5. 做完瘻管了可以用嗎

- A distal wrist radiocephalic AVF is placed for 6 weeks.
- The AVF has a pulsatile thrill near the anastomosis that fades proximally.
- On occlusion of the access proximally, the fistula does not augment.
- There are no visible accessory veins.
- Ultrasound finding: depth 2 mm, diameter 3.5 mm, and a straight segment cannulation length of 8 cm.

- Question 7: Which of the following indicates that the fistula may not be adequate?
  (a) The depth
  (b) The diameter
  (c) The length
  (d) All the parameters indicate a high likelihood of success

Rules of 6 for mature AVF

- **Vessel diameter >= 6 mm**
- Depth <= 6 mm from the surface of the skin
- Access flow volume >= 600 mL/min
- Straight segment for cannulation 6-10 cm

- Blood **flow >= 500 mL**/min + **Diameter>=4** mm
  - successful rate to cannulation : 95%
  - if neither, successful rate : 33%

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Case 6. 瘻管用久快壞了

- A new patient from another state.
- Under regular HD > 10 years via left upper brachiocephalic fistula use for 6 years.
- The AVF had many problems s/p “cleaned out”multiple times in the past.
- Difficult cannulation with 2 unsuccessful sticks.
- Physical examination of the fistula
  - enlarged and tortuous access
  - no collapse when arm elevation
- His arm is not swollen
- No collaterals on the chest wall while a scar of previous Perm-cath insertion

- Question 8: Which of the following statements is correct?

  (a) Sonography of his dialysis access is a difficult examination that requires extensive training.

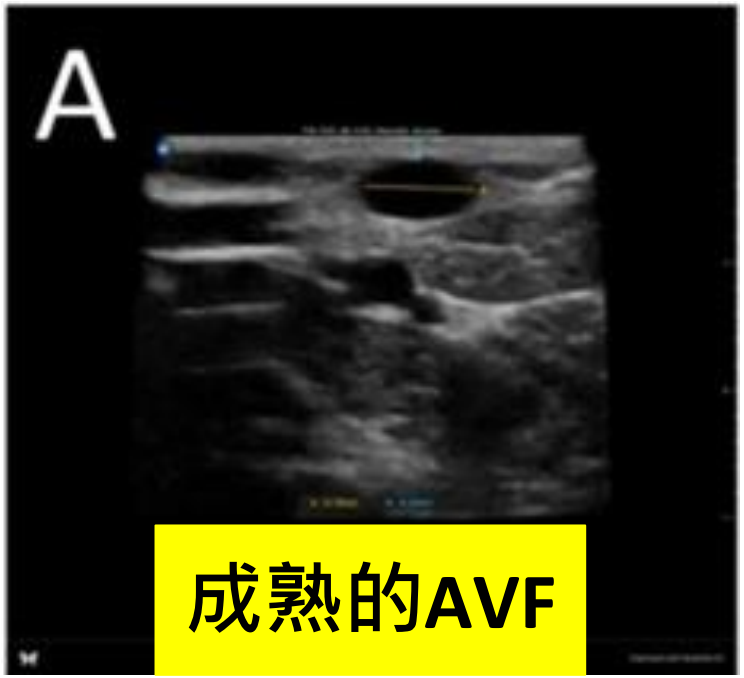
  (b) Sonography is the preferred method to detect central vein stenosis in this patient.

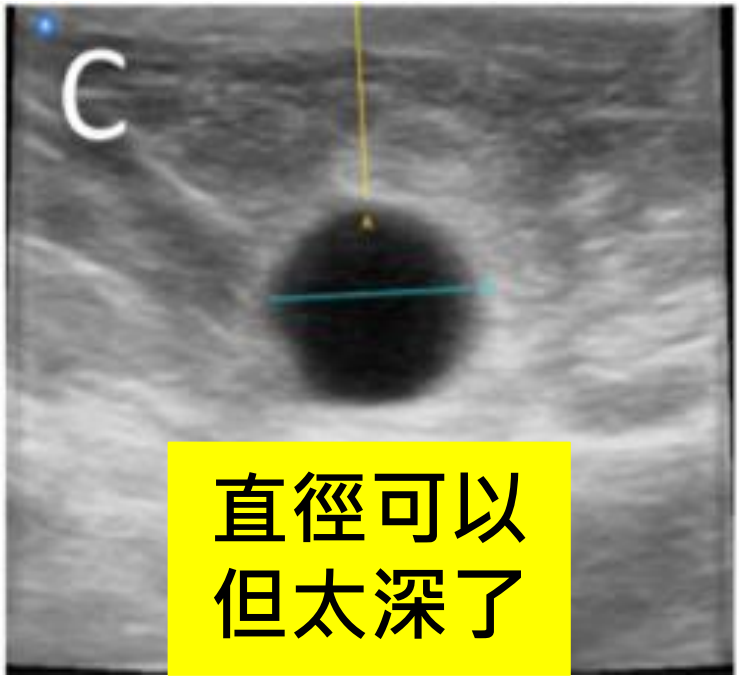
  (c) Sonographic assessment is not useful with him because he has a fistula rather than a graft.

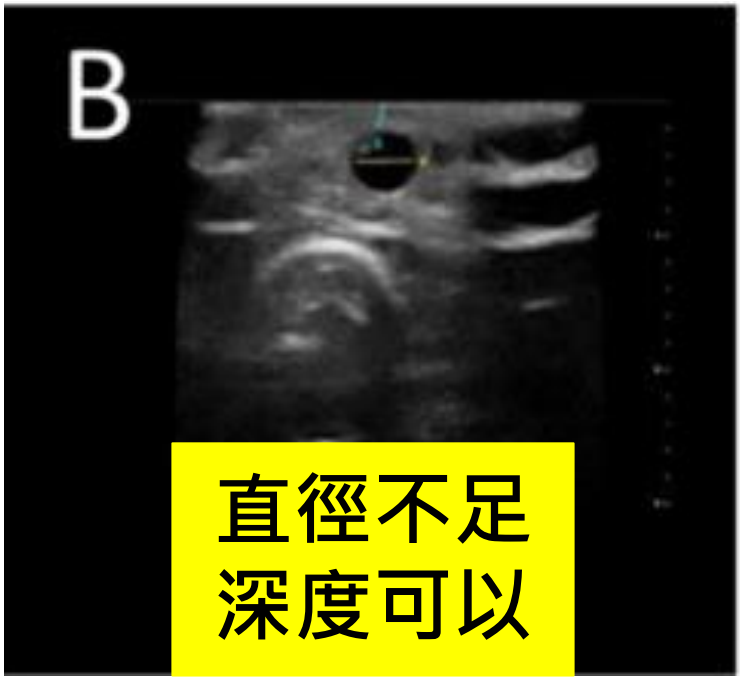
  (d) Ultrasound-guided cannulation may facilitate cannulation and minimize infiltrations in this patient.

Evaluation of Dialysis Access

- POCUS:
  - Intraluminal diameter
  - Depth from the surface of the skin
  - Accessory or collateral veins
  - Tortuosity
- Evaluate AVG: from fistulas by parallel echogenic lines
- For cannulation guidance if they are deep and to assess pseudoaneurysms, fluid collections and **reduce cannulation injuries (common within the first 6 months)**
- Detect the thrombosed access
- **Limitation:** direct visualization of **central veins**
  - direct measures of stenosis --> angiography, CT, MRI


A
成熟的AVF


C
直徑可以
但太深了


B
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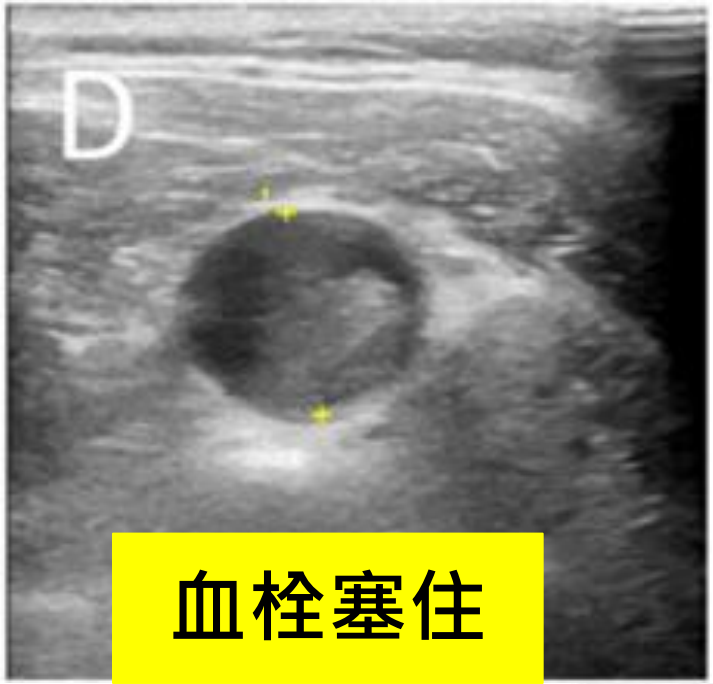
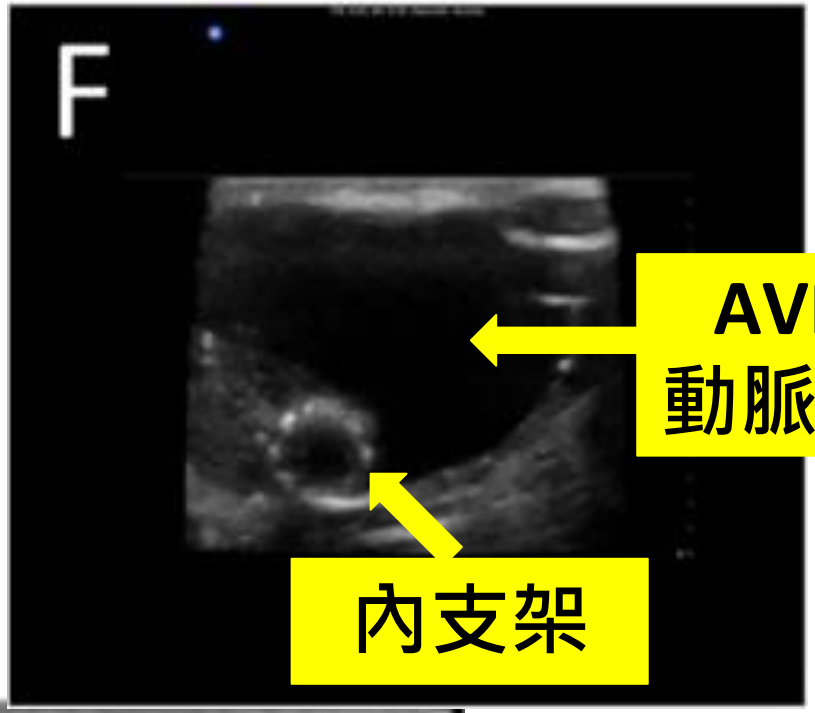
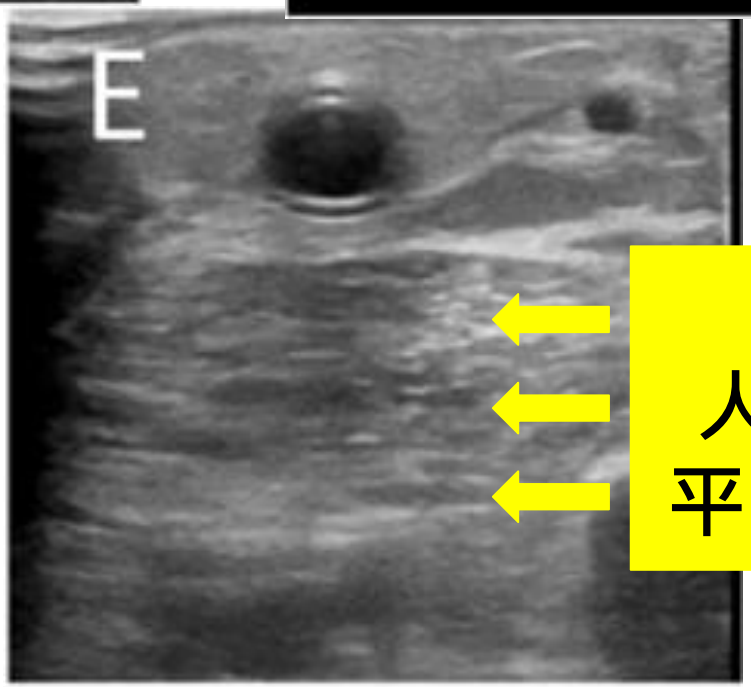
深度可以


D
血栓塞住


F
AVF
動脈瘤
內支架


E
AVG
人工物特徵:
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Volume Assessment

- Case 7. CKD with dyspnea: pulmonary edema
  → Lung ultrasonography (LUS)

- Case 8. Intradialytic hypotension
  → Focused echocardiography (FOCUS)

- Venous Excess Ultrasound Assessment (VEXUS) score

Case 7. 肺水腫

- At ED, an advanced CKD patient, CC. difficulty breathing
- Physical examinations
  - vital signs are stable with obvious respiratory distress.
  - unknown jugular venous pressure (not available)
  - clear lung sounds
  - bilateral trace pitting edema to the knees
  - chronic venous stasis changes

- Question 9: Which of the following lung ultrasound findings would be most consistent with cardiogenic pulmonary edema in this patient:

  (a) A-lines in all lung fields

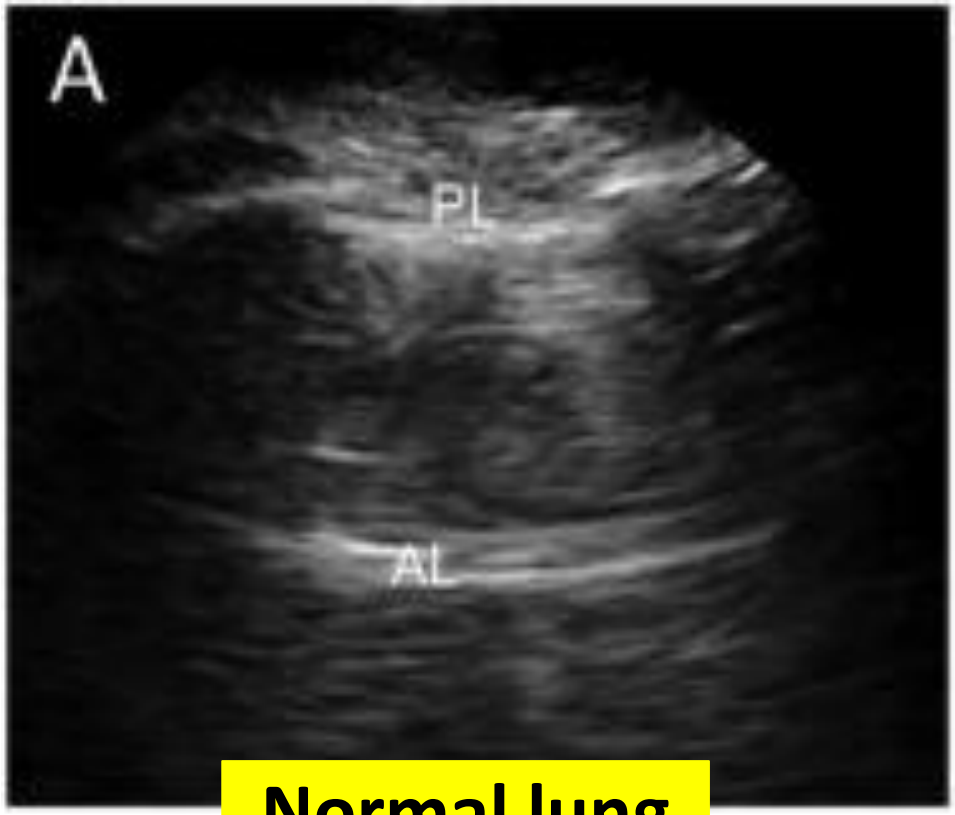
  (b) An anechoic area superior to the diaphragm on the left side only

  (c) Greater than 3 B-lines in 2 intercostal spaces, bilaterally

  (d) Hepatization of the lung bilaterally

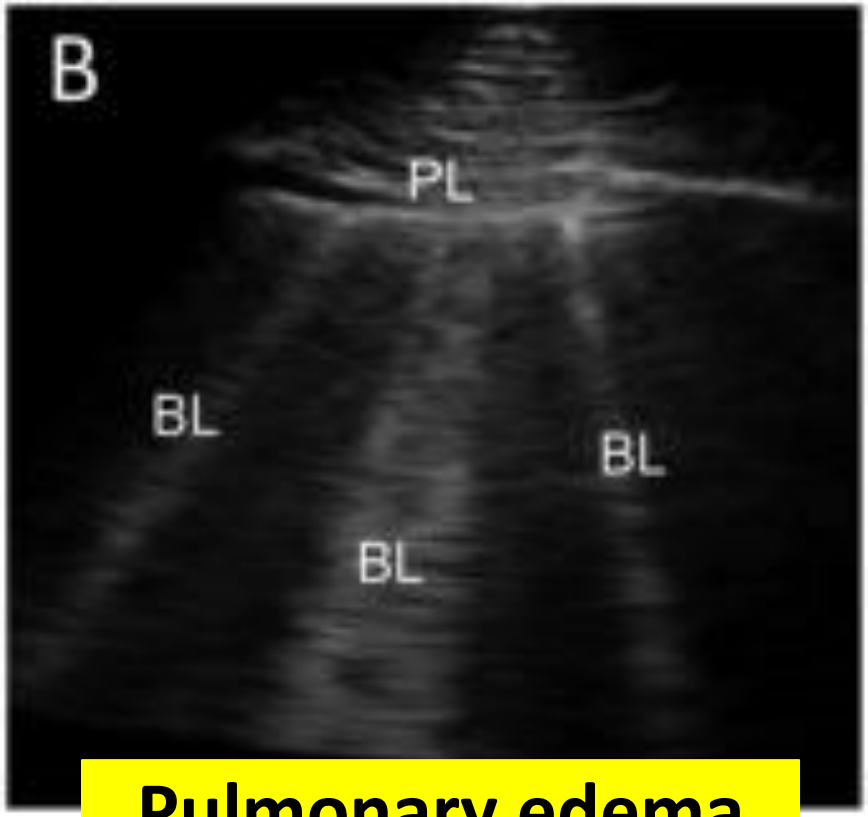
Lung ultrasonography (LUS)

- Via intercostal space(IS) to detect reverberation artifacts arising from the pleural surface
- Research settings: 28 IS; Clinical practice: IS*4/4 左右各四個肋間 (8-zone scan)
- The normally aerated lung --> **“A-line”**
  --> **PCWP < 13 mm** Hg: 90% specificity, **91% PPV**.
- The water-thickened interlobar septa --> **“B-line”**
  - 3 B-lines in an intercostal space: “B-region"
  - 2 B-regions bilaterally:“B-line pattern”
    --> **cardiogenic pulmonary edema**: 95% specificity and 97% sensitivity



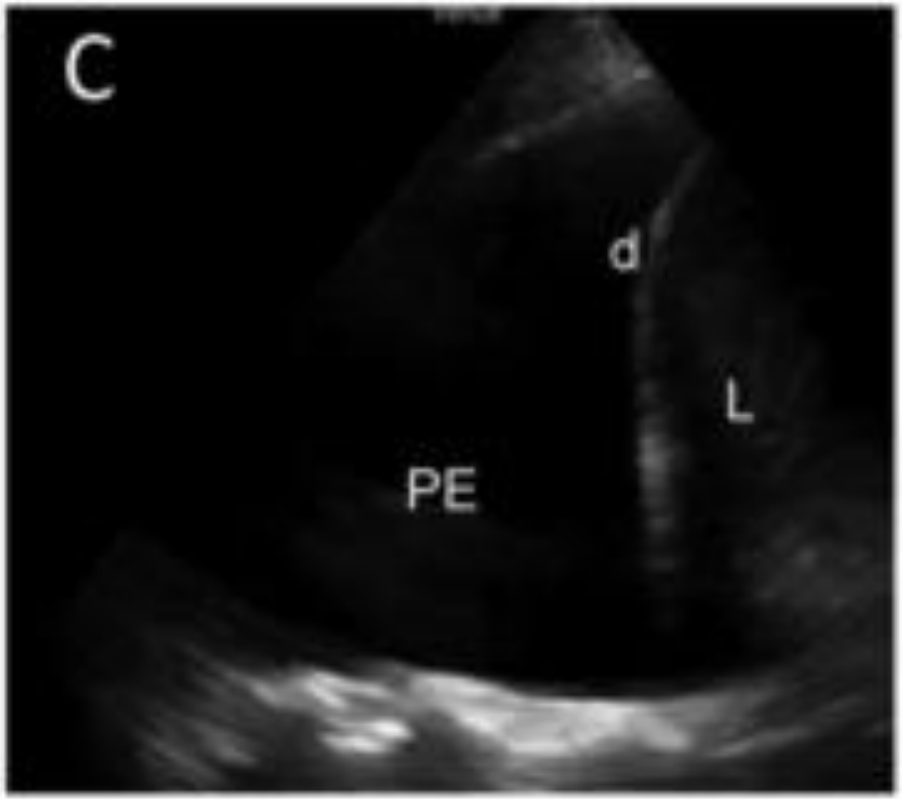
Normal lung
A-line

- Normally aerated lung.
- The pleural line (PL).
- The first A-line (AL).



Pulmonary edema
Several B-lines

- Pulmonary edema.
- The pleural line: 3 B-lines (BL).



- The hypoechoic area superior to the diaphragm (d) and liver (L)

  --> pleural effusion (PE).

- Consolidated(c) lung appears similar to the liver.

LUST Trial

- Lung Water by Ultrasound-Guided Treatment in Hemodialysis Patients (LUST) Trial
- N = 367 HD patients at high CV risk.
- Intervention: dry weight goal < 15 B-lines on a 28-zone scan.
- Follow-up: median of 1.5 years
- Outcomes:
  - Improved mortality in trend (no significance)
  - **Lower** episodes of **intradialytic hypotension (IDH)**
  - **Decreased hospitalizations** due to volume overload

Lung ultrasonography (LUS)

- In HD patients, **lung congestion** determined by quantification of B-lines across 28 intercostal spaces **predicts mortality** above and beyond traditional cardiac risk factors.

- Nephrologists must know how to identify
  - **consolidation**: hepatization of the lung --> pneumonia
  - **pleural effusion**s: an anechoic space above the diaphragm.
  - **pneumothorax**: lung sliding, barcode sign

Case 7. 肺水腫

- At ED, an advanced CKD patient, CC. difficulty breathing
- Physical examinations
  - vital signs are stable with obvious respiratory distress.
  - unknown jugular venous pressure (not available)
  - clear lung sounds
  - bilateral trace pitting edema to the knees
  - chronic venous stasis changes

- Question 9: Which of the following lung ultrasound findings would be most consistent with cardiogenic pulmonary edema in this patient:

  (a) A-lines in all lung fields

  (b) An anechoic area superior to the diaphragm on the left side only

  (c) Greater than 3 B-lines in 2 intercostal spaces,bilaterally

  (d) Hepatization of the lung bilaterally

Case 8. 透析中低血壓

- At ICU, a patient was undergoing hemodialysis.
- SBP drops from 120 to 85 mm Hg, with feeling of cool and clammy.
- The patient felt better after rinsed back.

- Question 10: Which of the following statements is true?

  (a) FOCUS has not been shown to improve diagnostic accuracy.

  (b) An IVC diameter measurement in a patient with increased intra-abdominal pressure is an accurate representation of right atrial pressure.

  (c) A small IVC with significant respiratory variation is associated with intradialytic hypotension.

  (d) POCUS cannot be used to evaluate venous excess.

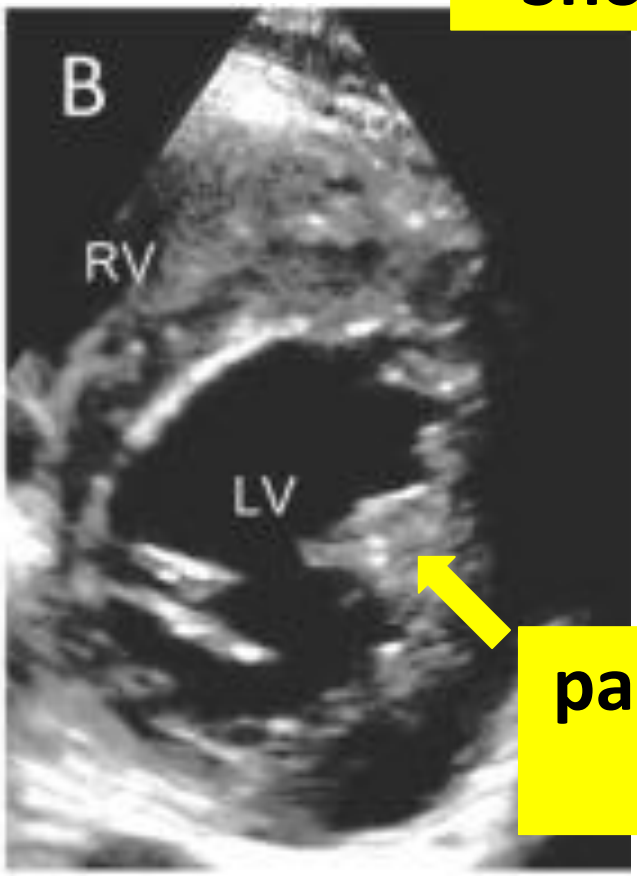
Volume assessment

- Focused echocardiography includes 4 basic views of the heart, including the IVC.
  - parasternal long axis
  - parasternal short axis
  - apical 4 chamber: probe at the point of maximal impulse
  - subxiphoid 4 chamber: probe underneath the xiphoid process -> IVC (trace hepatic v. -> IVC -> RA)
  - If abdominal distention or bowel gas --> axillary approach.

Parasternal long axis

- Size of the RV and LA
- LV systolic function

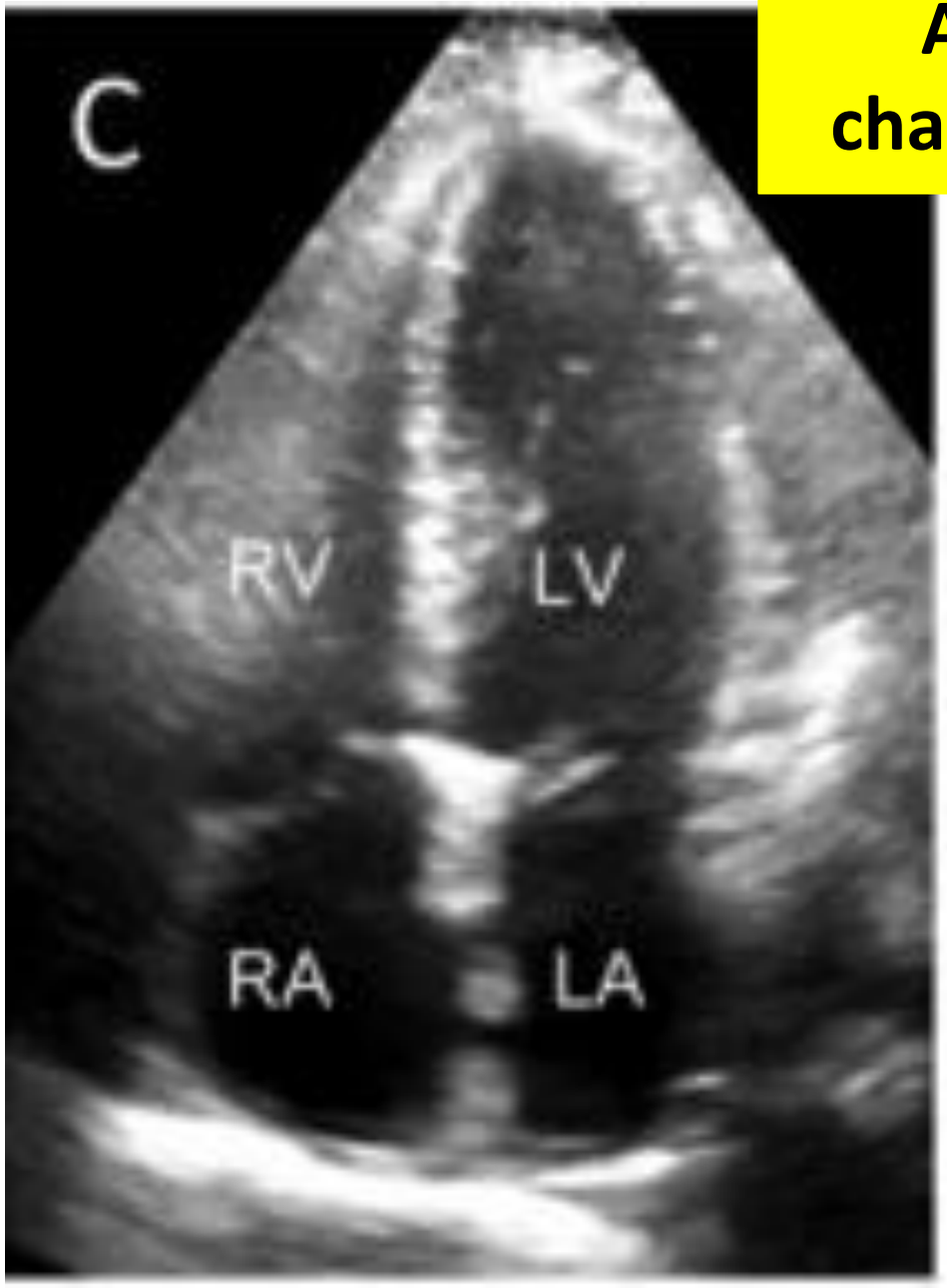
Short axis



papillary m.

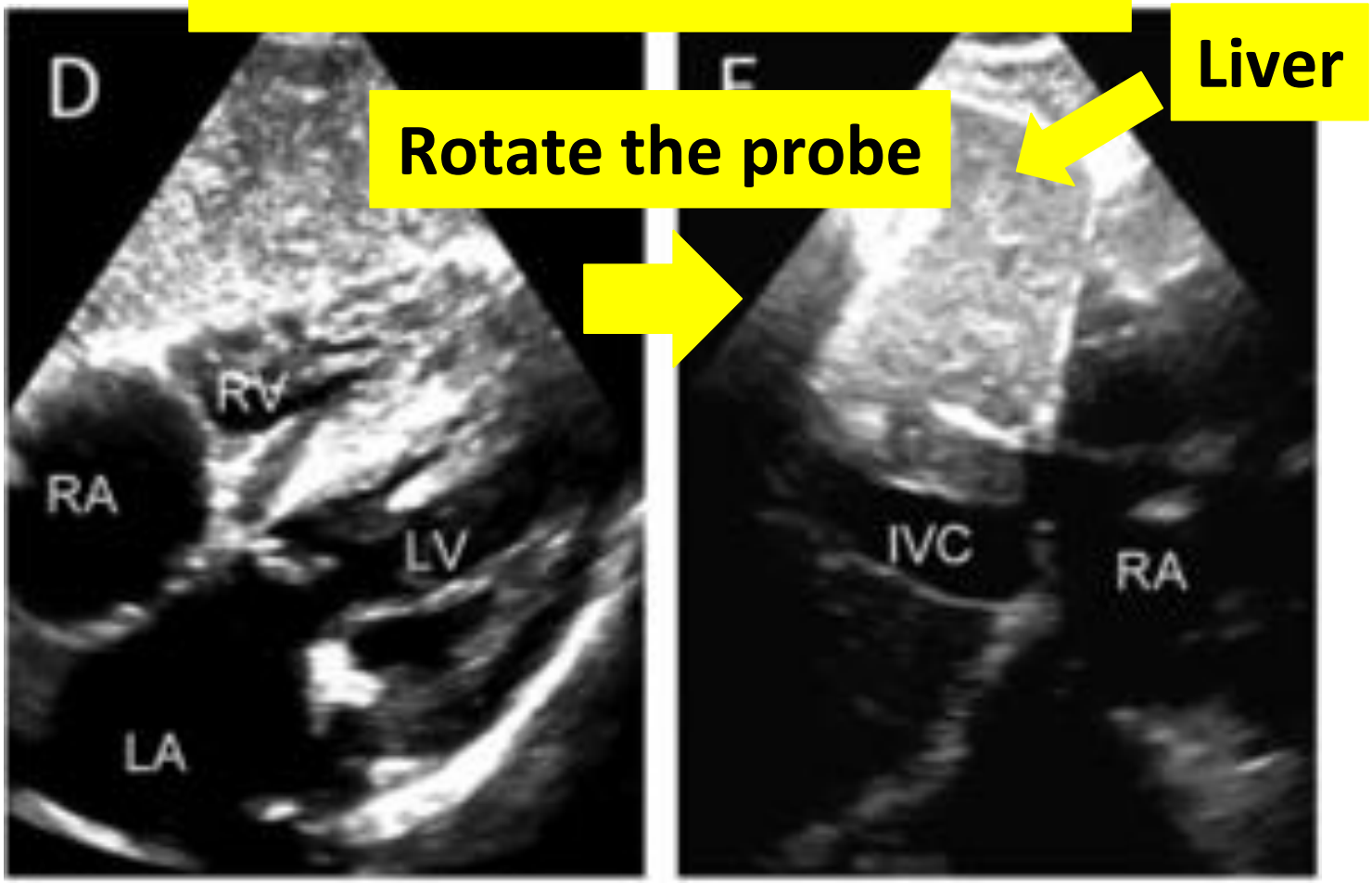
- LV systolic function
- RV shape (overload)

Apical 4-chamber view



- RV and LV relative size
- segmental abnormalities
- pericardial effusions

Subxiphoid 4-chamber view



- pericardial effusions
- estimating LV function
- measuring the IVC

Volume assessment

- Ultrasound measurement of the IVC --> assess intravascular volume.

- In patients who are spontaneously breathing
- **IVC diameter < 2.1 cm with > 50% collapse** following a quick inspiration (sniff) --> low RA pressure. **(0-5 mmHg), while 15-20 mmHg**

- Limitations
  - Mechanical ventilation
  - increased abdominal pressure

- Small IVC with significant IVC variation --> IDH and discontinuation of dialysis.
- Rule out systolic dysfunction in HD outpatient.

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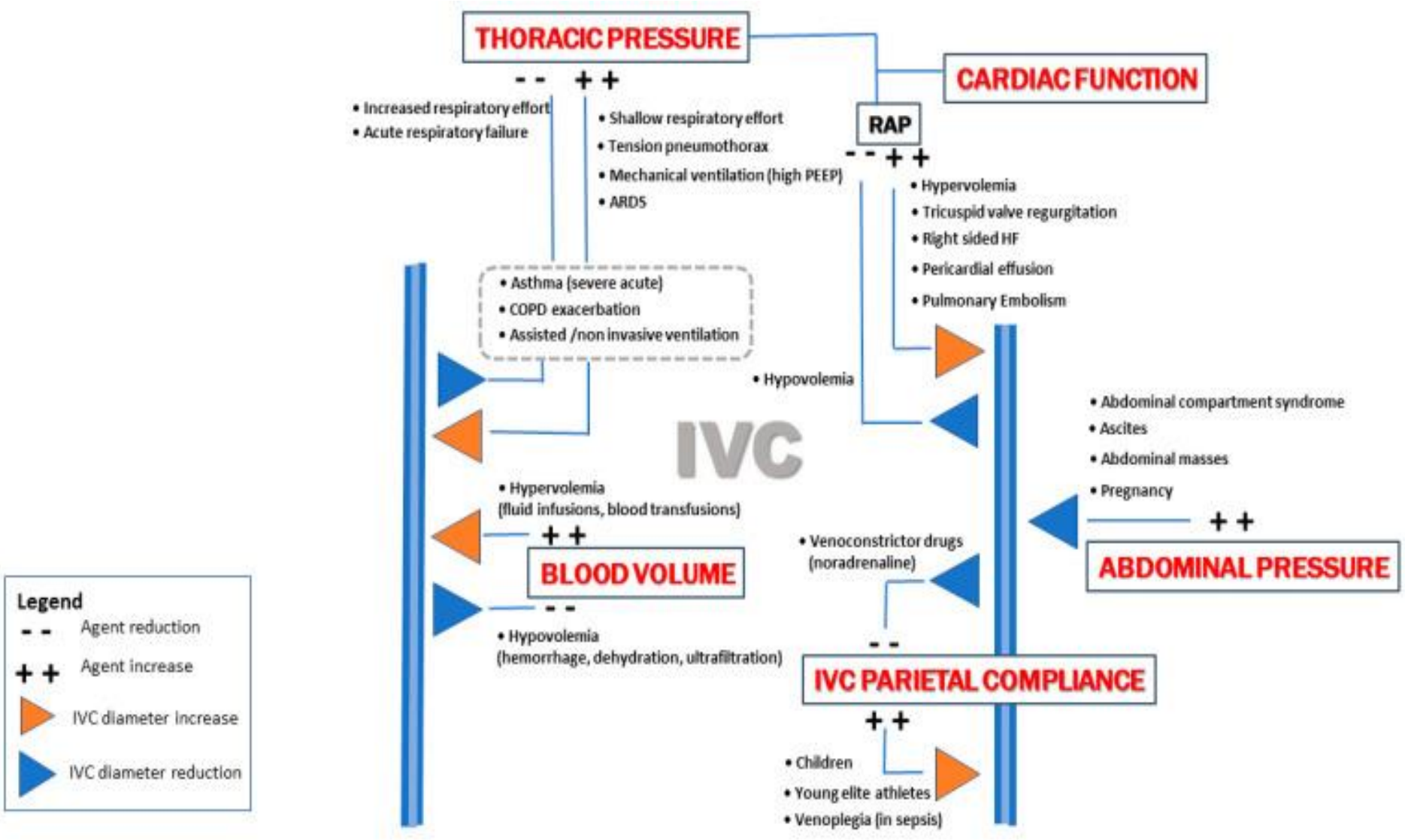
Main determinants of IVC diameter



Ref. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10053997/

Volume assessment

- A comprehensive **POCUS-based volume assessment**: both LUS and FOCUS.
  - **LUS:** extravascular lung water
  - **FOCUS:** cardiac filling pressures and intravascular volume.
- **Limitation**: detect **venous pressure excess**.
- Venous pressure -> determinant of kidney perfusion
- Patients with normal LV contractility, dry lungs but still venous congestion → benefit from volume removal.
- **VEXUS scores**
  - high VEXUS score--> predict AKI in patients s/p cardiac surgery.
  - **guide ultrafiltration or diuretic prescription.** (need RCTs)

VEXUS score (2020)

- Venous Excess Ultrasound Assessment (VEXUS) score
  1. Measure the IVC. → If the IVC is dilated, then hepatic venous waveforms via ECG tracings
  2. Measure portal vein pulsatility
  3. Image the intralobar renal arterial and veinous waveforms

- Grade 0-3 in each component -> Grade 3 means most congestion

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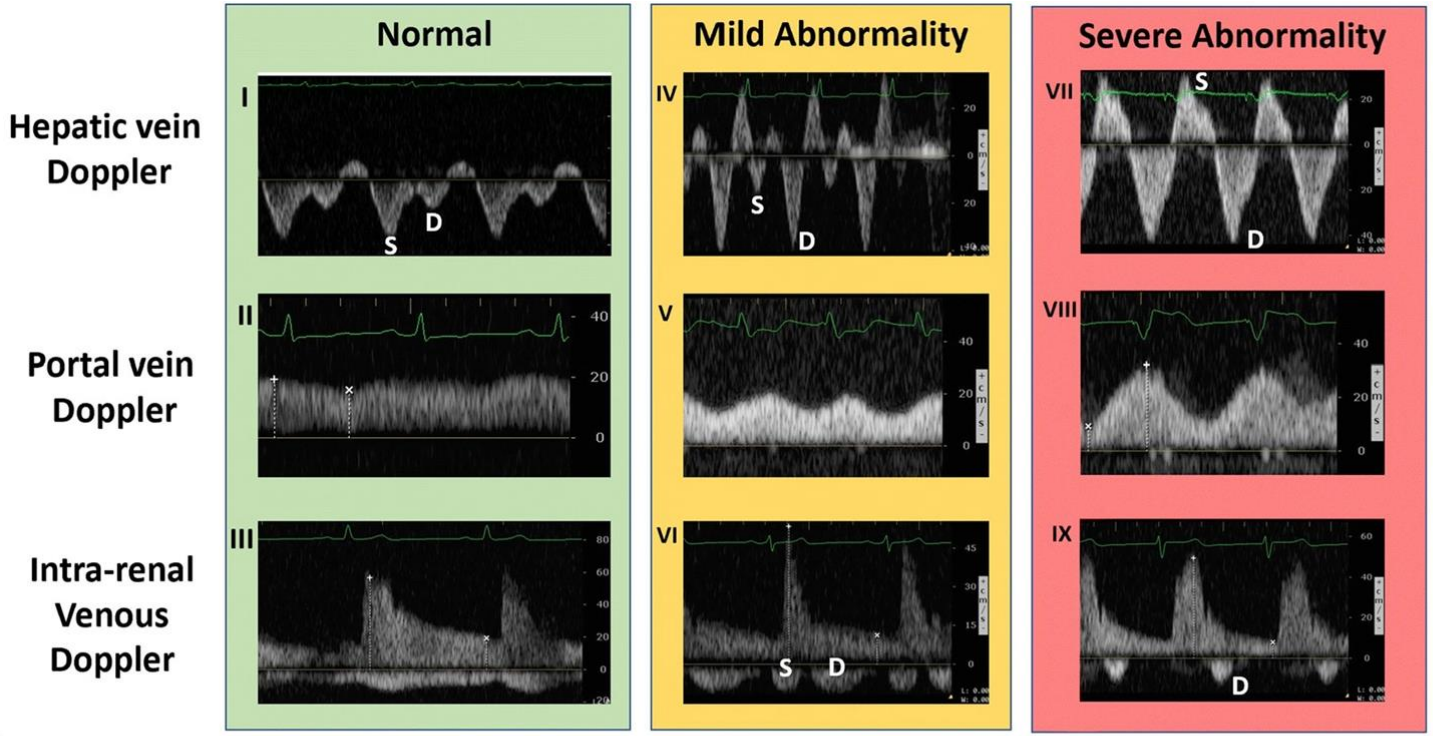

	VExUS A	VExUS B	VExUS C	VExUS D	VExUS E
Grade 0	IVC < 2 cm	IVC < 2 cm	IVC < 2 cm		
Grade 1	IVC ≥ 2 cm **Normal** patterns *(All three of : I, II, III)*	IVC ≥ 2 cm **Normal** patterns *(All three of : I, II, III)*	IVC ≥ 2 cm **Normal** patterns **or** **mild** abnormalitie(s) *(Any combination of : I, II, III, IV, V, VI)*	**Normal** patterns *(All three of : I, II, III)*	**Normal** patterns **or** **mild** abnormalitie(s) *(Any combination of : I, II, III, IV, V, VI)*
Grade 2: Mild congestion	IVC > 2 cm **Mild** abnormality in **at least one** pattern *(At least one of : IV, V, VI)*	IVC > 2 cm **Mild or severe** abnormality in **at least one** pattern *(At least one of : IV, V, VI, VII, VIII, IX)*	IVC > 2 cm **Severe** abnormalities in **at least one** pattern *(At least one of : VII, VIII, IX)*	**Mild or severe** abnormalities **in at least one** pattern *(At least one of : IV, V, VI, VII, VIII, IX)*	**Severe** abnormalities **in at least one** pattern *(At least one of : VII, VIII, IX)*
Grade 3: Severe congestion	IVC > 2 cm **Severe** abnormalities **in at least one** pattern *(At least one of : VII, VIII, IX)*	IVC > 2 cm **Mild or severe** abnormalities **in multiple** patterns *(At least two of : IV, V, VI, VII, VIII, IX)*	IVC > 2 cm **Severe** abnormalities **in multiple** patterns *(At least two of : VII, VIII, IX)*	**Mild or severe** abnormalities **in multiple** patterns *(At least two of : IV, V, VI, VII, VIII, IX)*	**Severe** abnormalities **in multiple** patterns *(At least two of : VII, VIII, IX)*

https://theultrasoundjournal.springeropen.com/articles/10.1186/s13089-020-00163-w

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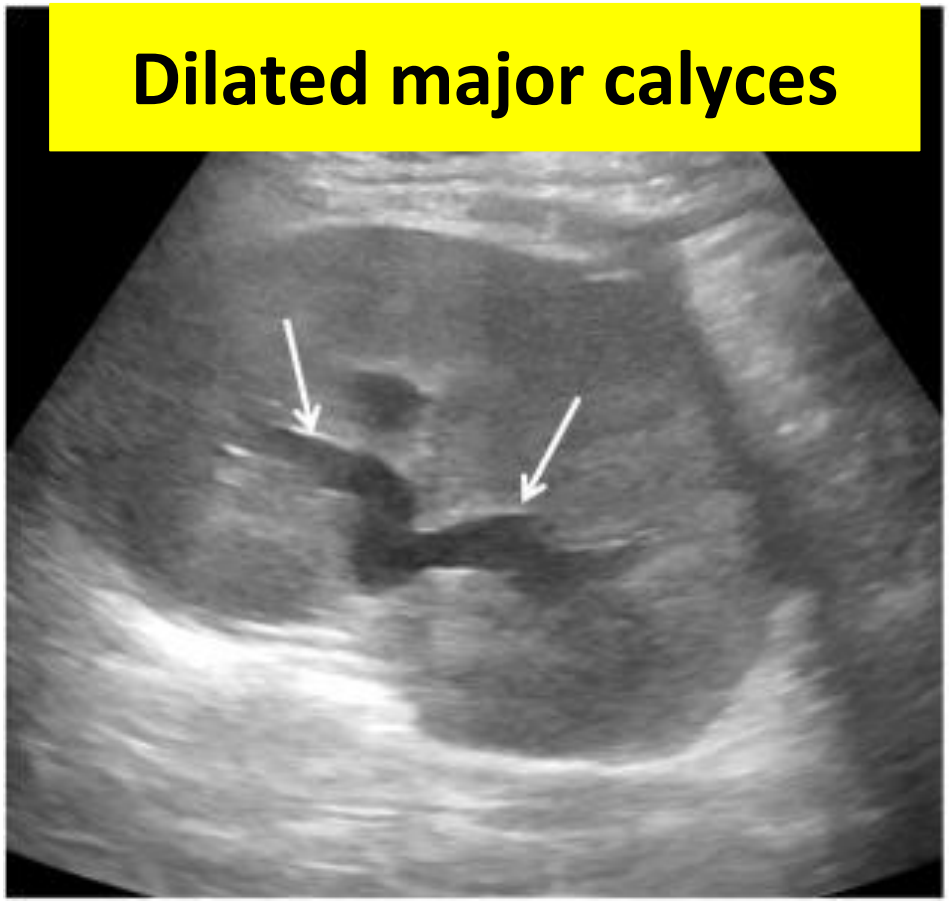
Kidney Transplant

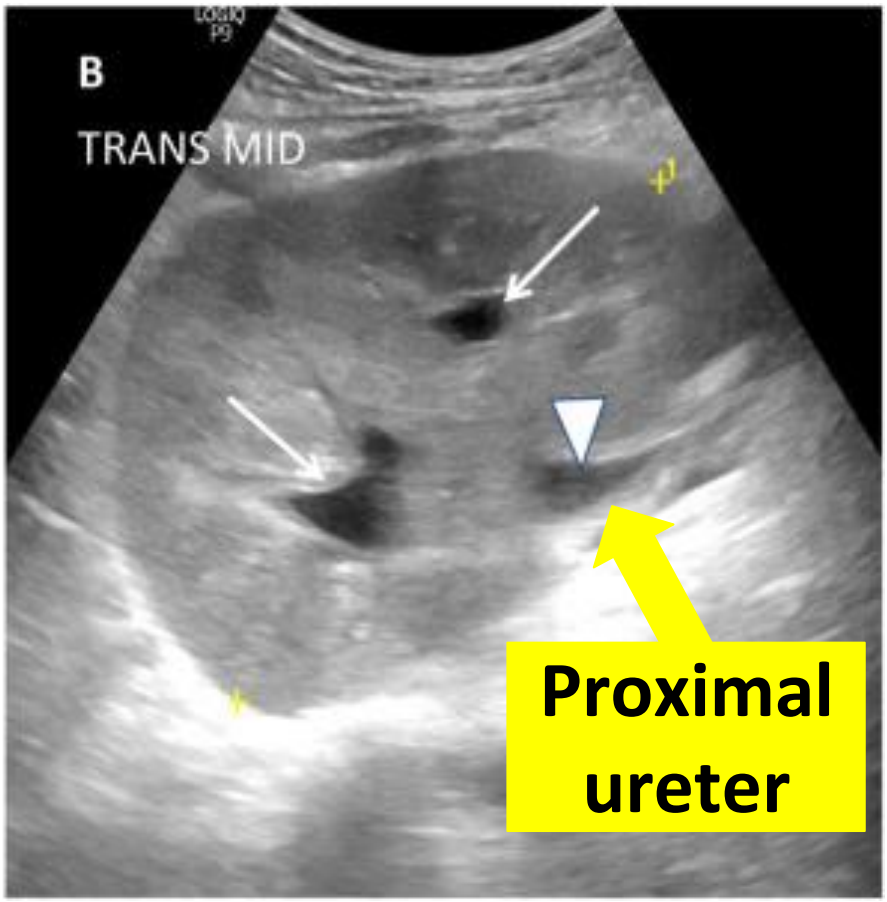
- Case 9. hydronephrosis in graft kidney
- Case 10. 66歳男性 post-renal AKI

Case 9. 腎移植後水腎

- A patient s/p kidney transplant, post OP 6 months, elevated serum creatinine level
- Renal sonogram
  - The kidney had a rounded shape, expanded cortex with obliterating the renal sinus fat. --> inflammation and/or edema.
  - Mild dilatation of major calyces and visible proximal ureter
  - No dilated urinary bladder

- Question 11: Which of the following is true?
  (a) This sonogram is diagnostic of acute rejection.
  (b) The sonogram is usually abnormal in acute rejection.
  (c) Resistive index is useful in diagnosing acute rejection.
  (d) Mild hydronephrosis can be seen in transplanted kidneys in the absence of obstruction.





- The nonspecific sonographic findings
  DDx: ATN, APN, viral infection, recurrent GN

Hydronephrosis in graft kidney

- The kidney is sonographically normal in most cases of acute rejection.
- The collecting system is commonly visualized in transplanted kidneys,
  - proximity to the ultrasound probe
  - **reflux** from the bladder due to **ectopic insertion of ureter**.
  - ureteral stents
- The degree of hydronephrosis in this patient does **not cause renal failure** and would **not explain the cortical expansion**. → indicated to renal biopsy
- Dilatation extending to the **minor calyces** --> clinically **significant hydronephrosis**.

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Case 10. 66歳男性

- A 66-year-old man with a kidney transplant presents with acute renal failure
- Bedside sonogram: moderate hydronephrosis

- Question 12: What is the likely cause of the hydronephrosis in this patient?

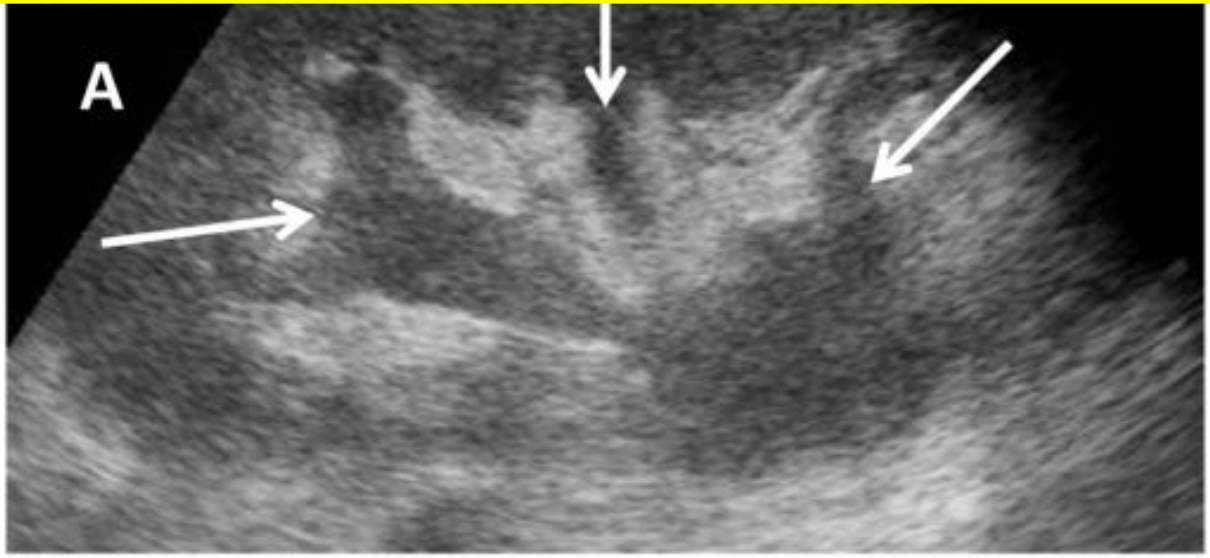
  (a) Ureteral stricture.

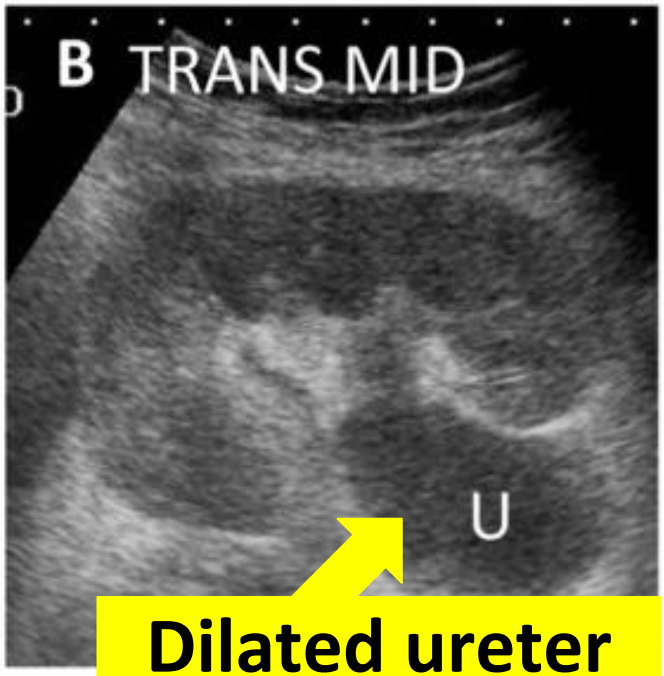
  (b) Stenosis at the ureteropelvic junction (UPJ).

  (c) Bladder outlet obstruction.

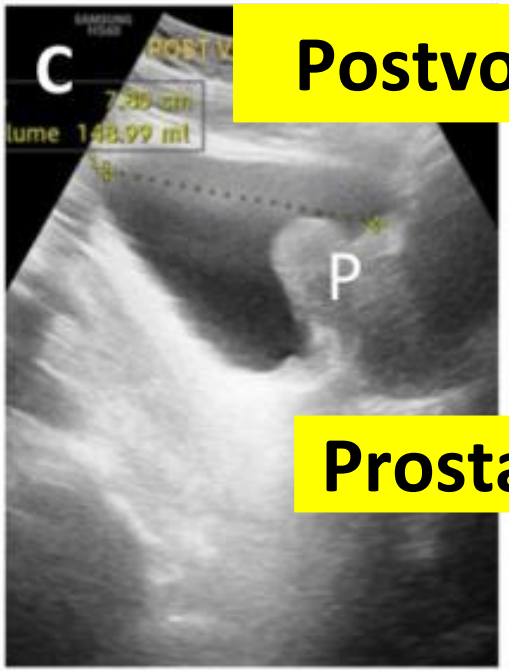
  (d) Occluded ureteral stent.

Dilatation extend to minor calyces





Dilated ureter



Postvoid

Prostate (P)

Cause to urinary tract obstruction

- A dilated collecting system can be visualized all the way to the bladder due to close to the probe and no overlying bowel gas.
- The dilated ureter traced to the bladder in other images, rules out UPJ obstruction and ureteral strictures are uncommon.
- No fluid collection consistent with a lymphocele (Rare after stents)
- Occlusion of stents should always be considered when they are present.
- Bladder retention is common → neurogenic bladder from diabetes.

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Conclusions

- The American Society of Diagnostic and Interventional Nephrology offers certification for nephrologists:
  - (1) evaluation of kidneys and bladder
  - (2) volume assessment
  - (3) dialysis access

- POCUS Pros
  - Mobile, widely available
  - Anatomical and functional assessments
  - No contrast or radiation
  - Noninvasive
  - Relatively inexpensive.

- POCUS Cons
  - **Time-consuming** for image acquisition and interpretation
  - Dependent on operator expertise

Take home messages

- AKI: ureteral jets, post renal
- CKD: cortical thickness, kidney length
- AVF assessment (pre/post OP)
- Rules of 6 for mature AVF
- Lung and heart echo and VEXUS score for volume assessment → predict IDH and guide UF

Thank you!