CKM Syndrome and the Missing Piece: Hemodynamics at the Core of Nephrology

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THE PARADOX AT THE HEART OF NEPHROLOGY

Nephrologists are daily managers of fluid balance, blood pressure, and blood perfusion. We prescribe ultrafiltration (UF), titrate diuretics, and decide on vascular access, yet often without direct visualization of the cardiovascular system. At the same time, the cardiovascular-kidney metabolic (CKM) syndrome has reframed the overlap between kidney and heart disease as the rule, not the exception.[1] This creates a paradox: despite working at the very crossroads of circulation and filtration, nephrology has historically relied on indirect, imprecise markers of hemodynamics – such as jugular veins, body weight, edema, and chest X-rays. These are late signs, notoriously subjective, and often misleading.

The burden of cardiorenal overlap is staggering. More than half of patients with heart failure (HF) show impaired kidney function; likewise, cardiovascular disease is the leading cause of death in chronic kidney disease. This interplay is not accidental; it is driven by shared mechanisms, including endothelial dysfunction, arterial stiffness, vascular inflammation and neurohumoral activation, and amplified by cardiovascular risk factors and volume overload.[1,2]

If one had to identify the most frequent and clinically significant challenge at the cardiorenal interface, it would be congestion, the leading cause of hospitalization in HF, loss of functional capacity, and a driver of mortality.[2-4] It appears in multiple nephrology scenarios: (i) in hemodialysis, where defining "dry weight" is often guesswork; (ii) in emergency and ward nephrology, where diuretic resistance or mixed cardiorenal-hepatic syndromes challenge management; (iii) in kidney transplantation, where post-operative fluid shifts and right-sided HF can masquerade as graft dysfunction; (iv) in vascular access, as new-onset high-output HF; and (v) in outpatient care, where volemia and hypertension management are essential when co-prescribing cardio-nephroprotective therapies.

Yet despite its ubiquity, congestion remains a blind spot in nephrology: the tools we traditionally use provide little real-time insight into intravascular pressures or the distribution of fluids between the interstitial and venous compartments.[3] If CKM syndrome highlights the inseparability of kidney and heart disease, congestion highlights the cost of not measuring what matters.

THE MISSING PIECE: ULTRASOUND AS A HEMODYNAMIC LENS

The advent of point-of-care ultrasound (POCUS) – in the form of the Venous Excess Ultrasound Score (VExUS), Lung Ultrasound (LUS) or Focused Cardiac Ultrasound (FoCUS) protocols – offers nephrology the opportunity to move beyond guesswork. These are not full echocardiographic studies; they are focused, reproducible, and clinically impactful assessments that answer specific hemodynamic questions at the bedside (Table 1).[4,5] A growing body of work has shown how even limited ultrasound (US) assessments can change decision-making and improve precision in daily practice.[6-9] Taken together, these modalities not only identify congestion but also help classify its phenotype – tissue versus vascular, left-sided, right-sided, or mixed – and thereby guide a more tailored therapeutic approach (Fig. 1).[10] The clinical impact is immediate, whether adjusting ultrafiltration targets with greater confidence, distinguishing true overload from

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other causes of weight gain, guiding diuretic therapy in resistant CKM despite rising creatinine, or explaining poor tolerance to AV fistula.[7-9] The ultrasound case, however, is not only technical but also professional and scientific. Hemodynamic assessment enables clinical decisions to be based on objective data, opening new research pathways, including VExUS-guided UF trials, FoCUS/LUS-based decongestion strategies in dialysis and transplantation, and even the integration of POCUS endpoints into CKM studies.[4,6-9] In a medical landscape where specialties increasingly overlap, differentiation matters. By mastering hemodynamics, nephrology strengthens its identity as the specialty that bridges circulation and filtration. Importantly, the nephrologists who can provide immediate hemodynamic insight position themselves better in shared multidisciplinary care settings and become indispensable in complex cases, whether in the dialysis unit, emergency department, or transplant ward.

CKM syndrome reminds us that kidney and heart disease are inseparable, and congestion is the shared burden that drives poor outcomes across dialysis, transplantation, and clinical nephrology. Ultrasound offers the missing piece: a way to move from empiricism to precision, while simultaneously strengthening nephrology's scientific voice, clinical relevance, and central role in multidisciplinary medicine. Nephrology has always been about more than numbers: it is about the circulation of fluids, the regulation of electrolytes and the balance of pressures. By embracing hemodynamics through US, nephrologists can not only treat CKM syndrome more effectively in all settings but also redefine the future of the specialty. The missing piece is literally in our hands.

Table 1. Hemodynamic and echocardiographic variables relevant for nephrology practice.

Clinical problem	Key findings	Ultrasound features (functional only)
Favors *backward* failure (congestive nephropathy)		
Elevated filling pressures	LA dilation, diastolic dysfunction, increased filling pressures	LA volume index > 34 mL/m^2, E/A > 2 (restrictive pattern), mean E/e´ >10-14
Significant valvular disease	Moderate to severe MR, MS or TR	-*
Pulmonary congestion	Alveolar edema, interstitial edema	Bilateral B-lines, pleural effusion
Pulmonary hypertension (indirect signs)	TR, RVOT dilation, elevated pulmonary artery velocity	TRV_{max} >2.8 m/s (PASP >40 mmHg), PAcT <105 ms
RV systolic dysfunction	RV dilation and/or hypertrophy, impaired systolic function	FAC <35%, TAPSE <17 mm, S´<9.5 cm/s
Right-sided volume overload	RA dilation, increased RAP, venous congestion	IVC diameter 2.1 cm with IVC collapsibility < 50%, abnormal (S/D < 1 hepatic vein pattern) or discontinuous flow patterns (portal/ renal veins) in VExUS
Favors *forward* failure (reduced renal perfusion)		
Low cardiac output	Low volume within the cavity, low stroke volume, impaired systolic function	Small cavity with "kissing-walls" LVOT VTI <17 cm or SVi < 35 mL/m^2 LVEF <50%, akinesias/ hypokinesias
Significant valvular disease	Moderate to severe AR, AS	-*
Reduced renal perfusion	Impaired renal autoregulation and perfusion	PP < 35-40 mmHg, MAP < 65 mmHg, resistive index > 0.70-0.75

Variables are organized by association with backward failure (congestive nephropathy) or forward failure (reduced renal perfusion). Backward failure reflects venous and systemic congestion, whereas forward failure reflects low cardiac output and reduced renal blood flow. Abbreviations: LA, left atrium; E/A, early-to-late transmitral filling velocity ratio; E/e', ratio of transmitral E-wave to early diastolic mitral annular velocity; MR, mitral regurgitation; MS, mitral stenosis; TR, tricuspid regurgitation; RV, right ventricle; RVOT, right ventricular outflow tract; TAPSE, tricuspid annular plane systolic excursion; FAC, fractional area change; S', tricuspid annular systolic velocity; TRVmax, maximum tricuspid regurgitant velocity; PASP, pulmonary artery systolic pressure; PAcT, pulmonary acceleration time; RA, right atrium; RAP, right atrial pressure; IVC, inferior vena cava; VExUS, venous excess ultrasound score; LV, left ventricle; LVOT, left ventricular outflow tract; VTI, velocity time integral; SVi, stroke volume index; LVEF, left ventricular ejection fraction; AR, aortic regurgitation; AS, aortic stenosis; PP, pulse pressure; MAP, mean arterial pressure; B-lines, sonographic vertical artefacts indicating pulmonary congestion. ***** *Morphologic dimensions and valve disease characterization (besides color Doppler) lie beyond the scope of this table. Some ultrasound features may apply to more than one "clinical problem."*

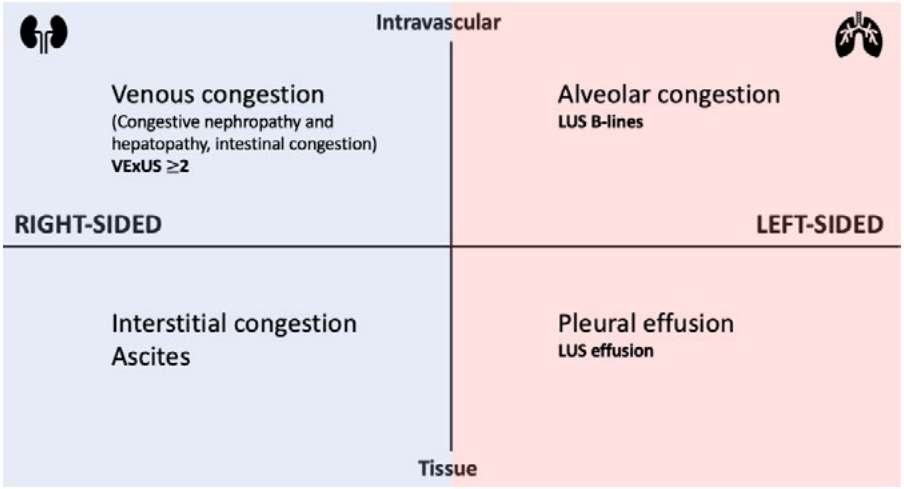

Figure 1. Congestion phenotyping according to laterality and compartment.

Congestion can be classified along two dimensions: right-sided, left-sided or mixed; and intravascular versus tissue (tecidular). This quadrant-based framework highlights how point-of-care ultrasound can not only detect congestion but also phenotype it, enabling more precise management strategies.

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