Improving AKI Care: Will Handheld POCUS Devices Have a Role?

By Abhilash Koratala and Amir Kazory

The prevalence of fluid overload among hospitalized patients with acute kidney injury (AKI) and its negative impact on prognoses has been increasingly recognized (1). Additionally, the potential contribution of fluid overload to kidney dysfunction (congestive nephropathy) highlights the need for reliable bedside methods for objective and reliable assessment of volume status (2). Point-of-care ultrasonography (POCUS) is a clinician-performed imaging procedure using ultrasound that addresses focused clinical questions at the bedside. Although appropriately trained nephrologists can perform scans ranging from simple kidney and bladder ultrasonography to comprehensive hemodynamic assessments, the resurgence of interest in POCUS is sparked by studies exploring the role of lung ultrasonography in patients receiving hemodialysis (3–5).

Affordable handheld ultrasound devices (HUDs) with improved portability have helped with the widespread use of POCUS. Most clinical ultrasonography systems, whether conventional or HUDs, use piezoelectric crystals within the transducers. These crystals vibrate, generating ultrasound waves when a potential difference is applied across the electrodes. Upon receiving an echo, they produce an electric signal that is displayed as an image. Transducers vary in their internal crystal makeup and arrangement, influencing how they display images and the frequencies at which they operate. Conversely, certain HUDs use a more recently developed microchip technology that generates ultrasound waves through a change in capacitance. These units, constructed on silicon using micromachining techniques, retain conventional ultrasound wave properties and image characteristics but enable the amalgamation of various transducer properties into a single unit, facilitating miniaturization of the equipment.

A recent study by Soares et al. (6) investigated the efficacy of a HUD using microchip technology for lung and inferior vena cava (IVC) ultrasonography in patients with AKI who were undergoing renal replacement therapy. In this observational study that included 50 patients who were critically ill, the investigators performed lung and IVC ultrasonography at the beginning of dialysis and 60 minutes into the session using the Butterfly IQTM microchip HUD as well as conventional piezoelectric crystal-based machines (Philips InnoSight or GE HealthCare Logiq TM P6). Dialysis prescription was not altered based on the ultrasonography findings. A strong correlation was found between the microchip and traditional piezoelectric-based ultrasound modalities in documenting the improvement in lung B-lines and IVC dynamics at two time points during hemodialysis. B-lines on the lung ultrasonography indicate extravascular lung water, usually secondary to elevated left heart filling pressures. At the same time, IVC ultrasonography is a standard echocardiographic parameter for estimating right atrial pressure in patients with spontaneous breathing. The study’s commendable use of an 8-zone lung ultrasonography method, as opposed to the more cumbersome 28-zone approach, enhances its practicality. Although acknowledging that the study’s microchip HUD is not the sole HUD available on the market, and most HUDs use piezoelectric technology, the study’s findings underscore the potential role of portable ultrasonography in nephrology practice. This aligns with the dynamic workflow of nephrologists who often traverse a variety of care settings.

It is, however, crucial to avoid overly optimistic conclusions extrapolating these findings to all POCUS applications. Lung ultrasonography relies on artifact interpretation, independent of high-resolution imaging capabilities; advanced settings suppressing artifacts are often disabled on larger machines to create a dedicated lung preset. Likewise, capturing images of the IVC does not usually warrant high-resolution devices, particularly considering that the average weight of patients in this study was 70 kg. Nonetheless, a comprehensive bedside hemodynamic evaluation requires more than lung and IVC ultrasonography, specifically a focused cardiac ultrasonography and selected Doppler applications (7, 8). Furthermore, IVC POCUS is not reliable in estimating right atrial pressure in patients who are mechanically ventilated. Therefore, the image quality of the device is a crucial factor for nephrologists seeking to enhance their proficiency in advanced POCUS applications. In this context, it is notable that the Butterfly IQTM device ranked lowest among four commonly used HUDs in the United States regarding image quality (9). Although the study contributes to the evolving landscape of POCUS applications in nephrology, a nuanced approach is essential, given the diversity of available devices and the ever-advancing nature of this technology. Table 1 presents a summary of the strengths and drawbacks of various methods for evaluating volume status in individuals with kidney diseases. ■

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References
### Table 1. Commonly used methods for evaluation of volume status

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<th>Method</th>
<th>Advantages</th>
<th>Limitations</th>
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| Physical examination                        | • Standard bedside evaluation: physicians do not require additional training.  
• Positive findings are significant.        | • Has poor sensitivity; misses a significant proportion of patients with volume overload. |
| Weight                                      | • Short-term changes in weight reflect fluid gain or loss.                   | • Errors can occur due to inadequate calibration of the equipment or comparing readings from different scales.  
• Can be done by the patient at their home.  | • Changes in weight do not reflect congestion due to fluid redistribution. |
| Intake-output chart                         | • Offers a snapshot of the patient’s fluid balance.                          | • Errors in documentation are common, particularly outside of the intensive care unit.  
• Does not reflect congestion due to fluid redistribution. | |
| Bioimpedance                                | • Provides information on total body, extracellular, and intracellular water enabling the calculation of absolute and relative fluid overload. | • Cannot discriminate between compartmentalized edema (ascites, pericardial, and peritoneal fluid) and increased total body water.  
• Does not assess intravascular volume.     | |
| Continuous hematocrit monitoring           | • Provides real-time data on relative changes in intravascular blood volume, allowing titration of the rate and volume of ultrafiltration. | • Application is limited to patients undergoing renal replacement therapy.  
• Is a nurse- or technician-driven modality; staff training is necessary.  
• Does not assess tissue congestion or extravascular lung water. | |
| Pulmonary artery catheterization           | • Provides insight into hemodynamic variables such as right atrial pressure, pulmonary artery pressure, pulmonary capillary wedge pressure, pulmonary vascular resistance, and cardiac output. | • Is invasive.  
• Monitoring hemodynamic changes in response to therapy is not possible outside specialized intensive care units.  
• Cannot provide information on the presence or absence of extravascular lung water. (Elevated pressure does not always imply volume.)  
• Does not provide information on the severity of venous congestion.  
• Errors can occur due to improper transducer calibration, leveling, zeroing, and over/underinflation of the balloon. | |
| IVC ultrasonography                         | • Provides an estimate of right atrial pressure.  
• Is relatively easy to perform; most HUDs are adequate. | • Is unreliable to estimate right atrial pressure in patients who are mechanically ventilated.  
• A plethoric IVC is not specific to volume overload (can be seen in conditions such as cardiac tamponade, pulmonary embolism, or pulmonary hypertension).  
• A small, collapsible IVC does not differentiate among hypovolemia, euvolemia, and a high-output cardiac state.  
• IVC can be small and collapsed despite elevated right atrial pressure in cases of intra-abdominal hypertension.  
• IVC collapsibility depends on the strength of breath, which is highly variable among patients. | |
| Internal jugular vein ultrasonography       | • Aids in the estimation of right atrial pressure.  
• Is particularly useful in cases in which the IVC is inaccessible or unreliable (e.g., cirrhosis).  
• HUDs generally provide adequate images.      | • Errors occur due to incorrect bed angle, excessive transducer pressure, and off-axes views.  
• The belief that the right atrial depth is 5 cm from the sternal angle has been demonstrated to be incorrect.  
• Precise estimation requires simultaneously focused cardiac ultrasonography.  
• Has variations in scanning protocols throughout the literature. | |
| Lung ultrasonography                        | • Detects and quantifies extravascular lung water.  
• Is more sensitive than a chest radiograph for cardiogenic pulmonary edema.  
• HUDs provide adequate images.               | • B-lines are not specific for pulmonary edema (can be seen in lung fibrosis, infections, contusion, etc.).  
• Some cases necessitate simultaneous measurement of left ventricular filling pressures using cardiac Doppler ultrasonography to differentiate cardiogenic and non-cardiogenic pulmonary edema. | |
| Venous Doppler (hepatic, portal, intrarenal, and femoral) | • Detects and quantifies systemic venous congestion.  
• Allows monitoring the response to decongestive therapy by repeating the measurements. | • Is an advanced skill that requires competence in Doppler ultrasonography.  
• Lack of simultaneous electrocardiogram may limit interpretation, particularly the hepatic vein waveform.  
• Does not differentiate pressure and volume overload.  
• Needs high-endHUDs or cart-based machines. | |
| Focused cardiac ultrasonography            | • Provides information on cardiac pump function, chamber enlargement, pericardial effusion, and gross valvular lesions.  
• Advanced users can estimate stroke volume, pulmonary artery pressure, and left ventricular filling pressures. | • Is an advanced skill; nephrologists performing Doppler assessments usually need certification in critical care echocardiography.  
• Needs high-end HUDs or cart-based machines.  
• The reliability is contingent on having adequate acoustic windows, influenced by the patient’s body habitus. |