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Utilizing a novel point of care ultrasound (POCUS) protocol to guide diuresis – A case series

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A B S T R A C T

Volume assessment is an important, but challenging but crucial aspect of patient care. Fluid balance is affected by volume expansion, sepsis/shock states, cardiac and kidney failure and is present in the majority of patients. Similarly, in critically ill patients on diuretics, both excessive and inadequate diuresis can worsen outcomes.

Chest X-ray (CXR) and auscultation are poorly predictive of volume status, while bioimpedance and blood volume monitoring have limitations at the bedside [4]. Inferior vena cava (IVC) diameter as measured by POCUS is a marker of intravascular volume that can provide a real-time assessment to guide diuresis.

The Reverse Falls Protocol combines lung and IVC US to enable the clinician to visualize, in real-time, the patient's intravascular and extravascular volume and to set diuresis goals. We present a series of cases where euvolemia was achieved using the principles described by O'Hara, Chabra & Ahmad's Reverse Falls Protocol.

1. Introduction

Volume assessment is an important, but challenging aspect of patient care; therefore, evaluation of volume overload, and accurate diuresis is crucial to successful interventions. In patients with end-stage renal disease, hypervolemia is associated with hypertension and structural heart disease [1,2], while intradialytic hypovolemia leads to hypotension, dementia and worse quality of life [3]. Similarly, in critically ill patients on diuretics, both an over-diuresis and an inadequate diuresis can worsen outcomes.

Chest X-rays and auscultation are poorly predictive of volume status, while bioimpedance and blood volume monitoring have limitations at the bedside [4]. Inferior vena cava (IVC) diameter as measured by POCUS is a marker of intravascular volume that can provide a real-time assessment to guide diuresis, including patients undergoing hemodialysis for pulmonary edema [5–8]. Similarly, B-line artifacts detected on lung US may be clinically correlated with pulmonary edema [9].

The Reverse Falls Protocol combines lung and IVC US to enable the clinician to visualize, in real-time, the patient's intravascular and extravascular volume and to set diuresis goals. We present a series of cases where euvolemia was achieved using the principles described by O'Hara, Chabra & Ahmad's Reverse Falls Protocol [10]. Diuretics were initiated if IVC minimum diameter (D-min) by US was 2.1-cm and if B-lines were predominant on lung ultrasound. The IVC maximum diameter (D-max) and lung US are used to monitor response with reassessment every 6 hours, until IVC D-max has decreased to 1.0-cm. Furthermore, lung ultrasonography displayed artifact conversion from a B-line to an A-line predominant pattern.

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2. Case reports

2.1. Case 1

A 34-year-old male presented with worsening dyspnea. Echocardiogram showed an Ejection Fraction (EF) of 10% with a pro b-type natriuretic peptide (pro-BNP) of 11,039 pg/mL. He was started on diuretics for decompensated heart failure; however, required intubation for an acute stroke. Pulmonary service was consulted for failure to wean from the ventilator. On physical exam, he was tachypneic, with bilateral leg edema, and diffuse, bilateral B-lines on lung ultrasonography.

The Reverse Falls Protocol was implemented with increasing diuresis until the IVC D-max was smaller than 1-cm. At this time B lines remained evident on chest US; therefore, albumin was utilized for intravascular volume expansion followed by diuresis. This regimen continued until the chest ultrasound showed predominant A-lines (Fig. 1). He was subsequently extubated on day 9 of the Reverse Falls Protocol and was net negative 20.69L.

2.2. Case 2

A 74-year-old female with insulin-dependent diabetes, breast cancer who presented with worsening lethargy two weeks after radiation. On physical exam, she was tachycardic and somnolent, with oxygen saturation of 97% on room air. Laboratory studies were significant for a serum glucose of 986 mg/dL, bicarbonate <6 mmol/L and an anion gap of 40. She was admitted to the medical intensive car unit (MICU) and given intravenous fluids and insulin. Her hospital course was complicated by mechanical ventilator for hypoxic respiratory failure secondary to pulmonary edema. She was started on furosemide 40 mg twice daily. The Reverse Falls Protocol was used to enhance diuresis by increasing diuretic doses until lung US displayed artifact conversion from a B-line (Fig. 3) to an A-line predominant pattern. She was subsequently extubated on day 4 of the Reverse Falls Protocol and was net negative 8.07L.

2.3. Case 3

A 66-year-old female with history of type III gastric carcinoid tumor was admitted to the surgical service for gastrectomy. Post-operatively, she developed bilateral pleural effusions for which chest tubes were placed. Physical exam revealed tachypnea, and reduced breath sounds bilaterally, with oxygen saturation of 88% on 40% FIO₂. She clinically declined and was placed on mechanical ventilation for hypoxemic respiratory failure secondary to pulmonary edema. Initial lung US revealed predominant B-lines, while IVC ultrasound showed D-min of 2.1-cm. She was started on furosemide 80 mg twice daily. The Reverse Falls Protocol was used to enhance diuresis until lung US displayed artifact conversion from a B-line to an A-line predominant pattern. She was subsequently extubated on day 5 of the Reverse Falls Protocol and was net negative 11.13L.

2.4. Case 4

An 88-year-old man with history of atrial fibrillation was admitted with hematochezia of one week. On day 2 of admission, he was found to be hypotensive, tachycardic with oxygen saturation of 89% on nasal cannula 4L/min. Laboratory studies were significant for hemoglobin of 8g/dL (13.2g/dL at presentation). He subsequently had a cardiac arrest, was resuscitated, and transferred to the MICU on mechanical ventilation where he was diagnosed with pulmonary edema. IVC ultrasound showed D-min of 1.93cm (Fig. 2). Esophagogastroduodenoscopy showed no active bleeding and he was given packed red cells infusions and started on an intravenous infusion of furosemide. The Reverse Falls Protocol was used to enhance diuresis until lung US displayed artifact conversion from a B-line to an A-line predominant pattern. He was subsequently extubated on day 5 of the Reverse Falls Protocol and was net negative

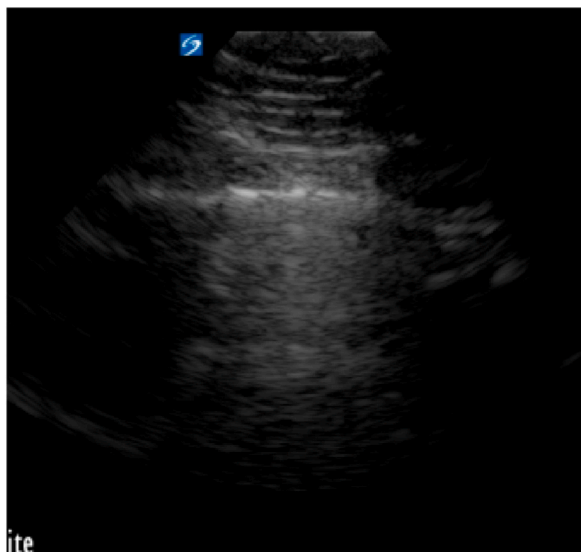


Fig. 1. Case 1. Anterior chest ultrasound showing A-lines.



Fig. 2. Case 4. IVC ultrasound showing IVC minimum diameter (dmin) 1.93cm.

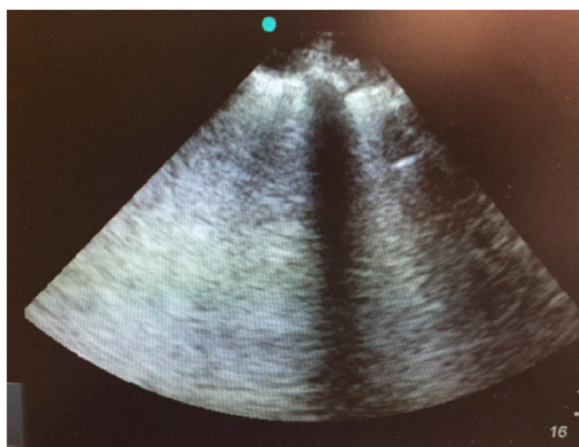


Fig. 3. Case 5. Anterior chest ultrasound showing B-lines.

7.44L.

2.5. Case 5

A 63-year-old male with history of radical cystectomy for bladder cancer was admitted for an open cholecystectomy, and left ureteral re-implant into orthotopic neobladder. His post-operative course was complicated by transaminitis and obstructive hyperbilirubinemia for which endoscopic retrograde cholangiopancreatography was performed to remove stone. He developed worsening dyspnea for which pulmonary team was consulted. On physical exam, he was tachypneic and tachycardic with oxygen saturation of 88% on Nasal Cannula 4L/min. He was transitioned to Bilevel Positive Airway Pressure (BiPAP) and transferred to the MICU for acute hypoxic respiratory failure secondary to pulmonary edema. Laboratory studies were significant for proBNP 62,352pg/mL and lung US with escalating doses based on the Reverse Falls Protocol. The Reverse Falls Protocol was used to enhance diuresis until lung US displayed artifact conversion from a B-line to an A-line predominant pattern. He subsequently avoided intubation and was taken off BiPAP on day 8 of the Reverse Falls Protocol and was net negative 24.33L.

3. Discussion

Compared to the last two decades, POCUS is now considered an adjunct to the standard of care for assessing a patient's hemodynamics and their intravascular and extravascular volume status. While traditional radiology and physical examination continue to serve a vital purpose, POCUS adds to the armamentarium especially with the added feature of frequent, real-time assessment and should be interpreted in conjunction with other clinical parameters. The goal of diuresis in the hypervolemic patient is to achieve a baseline clinical status devoid of pulmonary edema while avoiding the deleterious effects of over-diuresis; therefore, the Reverse Falls Protocol provides an objective method of achieving it.

We describe five cases where key elements from the Reverse Falls Protocol are used to guide diuresis in the hypervolemic patient with pulmonary edema. All patients improved with the combined use of lung and IVC ultrasound in assessing both the extravascular and intravascular spaces. Altogether, these five cases had net diuresis on average 2.3L per day with no events of hypotension or

worsening renal function. Given the outcomes of these cases we recommend consideration of the Reverse Falls Protocol to guide diuresis for pulmonary edema. We emphasize that there is need for a longitudinal prospective study of the Reverse Falls Protocol.

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