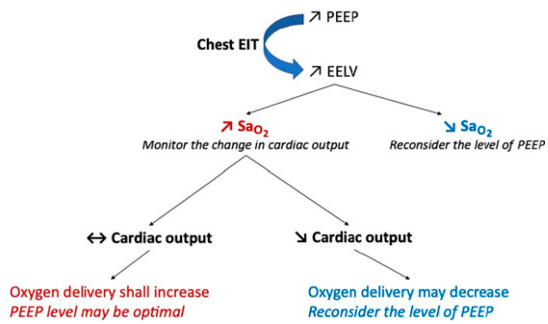

Figure 1. Determinants of oxygen delivery. EELV = end-expiratory lung volume; EIT = electrical impedance tomography; PEEP = positive end-expiratory pressure; Sa_{O_2} = oxygen arterial saturation.

of increasing PEEP in this setting. Increasing PEEP increases intrathoracic pressure and leads to challenge the cardiac performance, which may result in a drop in cardiac output (3, 4). Despite observing an increase in Sa_{O_2} during incremental PEEP, the drop in cardiac output may eventually induce a decrease in oxygen delivery (Figure 1). This effect has been notably reported in patients with COVID-19 (5, 6). Calculation of oxygen delivery requires the determination of cardiac output, hemoglobin concentration, and Sa_{O_2}, which can be obtained easily at the bedside. Unfortunately, arterial pressure monitoring is not accurate to assess changes in cardiac output, which can be noninvasively measured with echocardiography. Therefore, assessing the impact of PEEP on hemodynamics and its influence on oxygen delivery to determine the optimal PEEP for patients with ARDS could complement the method proposed by Jonkman and colleagues. It would provide a more comprehensive understanding of the effects of PEEP and help optimize ventilatory strategies for patients with ARDS. ■

Author disclosures are available with the text of this letter at www.atsjournals.org.

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References

1. Jonkman AH, Alcala GC, Pavlovsky B, Roca O, Spadaro S, Scaramuzzo G, *et al.*; Pleural Pleasure Working Group (PLUG). Lung Recruitment Assessed by Electrical Impedance Tomography (RECRUIT): a multicenter study of COVID-19 acute respiratory distress syndrome. *Am J Respir Crit Care Med* 2023;208:25–38.
2. Sahetya SK, Goligher EC, Brower RG. Fifty years of research in ARDS. Setting positive end-expiratory pressure in acute respiratory distress syndrome. *Am J Respir Crit Care Med* 2017;195:1429–1438.
3. Jardin F, Farcot JC, Boisante L, Curien N, Margairaz A, Bourdarias JP. Influence of positive end-expiratory pressure on left ventricular performance. *N Engl J Med* 1981;304:387–392.
4. Jardin F, Vieillard-Baron A. Right ventricular function and positive pressure ventilation in clinical practice: from hemodynamic subsets to respirator settings. *Intensive Care Med* 2003;29:1426–1434.
5. Bonny V, Janiak V, Spadaro S, Pinna A, Demoule A, Dres M. Correction to: Effect of PEEP decremental on respiratory mechanics, gas exchange, pulmonary regional ventilation, and hemodynamics in patients with SARS-Cov-2-associated acute respiratory distress syndrome. *Crit Care* 2020;24:675.
6. Barthélémy R, Beaucoté V, Bordier R, Collet M, Le Gall A, Hong A, *et al.* Haemodynamic impact of positive end-expiratory pressure in SARS-CoV-2 acute respiratory distress syndrome: oxygenation versus oxygen delivery. *Br J Anaesth* 2021;126:e70–e72.

Reply to Jimenez and Hyzy and to Le Stang and Dres

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From the Authors:

We thank Jimenez and Hyzy as well as Le Stang and Dres for carefully reading our article "Lung RecruitmEnt assessed by eleCtRical Impedance Tomography (RECRUIT): A Multicenter Study of COVID-19 ARDS" (1). The authors of both letters acknowledged the importance of our work and the relevance of our findings, in particular, the discrepancy that we report between the electrical impedance tomography (EIT)–based optimal positive end-expiratory pressure (PEEP) level where overdistention and collapse are jointly minimized (EIT crossing point) and the PEEP related to the highest respiratory system compliance. This stresses the complex relationship between recruitment and compliance and the potential benefit of EIT for assessing regional effects of PEEP on the lungs. Furthermore, both letters mentioned the importance of the negative correlation between oxygenation and overdistention at higher PEEP levels that we found (1), possibly specific to coronavirus disease (COVID-19) pathology. This could trigger a vicious circle of increasing levels of PEEP and increasing overdistention; such harmful effects may, indeed, occur with conventional PEEP approaches (PEEP-$F_{I_{O_2}}$ tables), as also mentioned by Jimenez and Hyzy. Le Stang and Dres further stressed the importance of assessing the effects of PEEP on hemodynamics in addition to the impact on the lungs, and

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we agree with these authors that this important component should not be neglected. However, performing cardiac output measurements at different PEEP steps would have added a great deal of complexity to the protocol. Of note, performing cardiac ultrasound could influence the reliability of the EIT monitoring (primarily, EIT signal disturbances related to positioning of the probe on the thorax), and such measurements should ideally be performed consecutively. Measurement of regional ventilation/perfusion by contrast-enhanced EIT (saline bolus)—a feature that has recently been developed—and/or performing volumetric capnography would also be an interesting approach to studying the effects of increasing levels of PEEP on macro- and microcirculation. We are lacking now a precise guidance on how these two complex approaches could be directly used.

Jimenez and Hyzy mentioned that the EIT-based PEEP level did not differ from the highest compliance approach in nonrecruitable patients. To clarify, in the high-recruitability patients, this difference was nonsignificant, as indicated in Figure 5 of our article (1). Overall, the EIT crossing point yielded a slightly higher PEEP level than with the compliance approach, but large individual variability was found. We agree that differences in recruitability likely explain the differences in optimal PEEP level by means of any PEEP setting approach (conventional or EIT based) in earlier ARDS studies, and that assessing lung recruitability should be part of a personalized mechanical ventilation strategy. EIT application is a feasible and promising technique for assessing lung recruitability at the bedside. One could imagine starting with the recruitment-to-inflation ratio (2) and then using EIT if the lung is found to be recruitable. Individualization of PEEP setting using EIT to improve outcomes is a topic of ongoing research (including a randomized clinical trial: ClinicalTrials.gov identifier NCT 05307913), and we look forward to further investigating the role of EIT to optimize personalized mechanical ventilation. ■

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References

1. Jonkman AH, Alcala GC, Pavlovsky B, Roca O, Spadaro S, Scaramuzzo G, *et al.*; Pleural Pressure Working Group (PLUG). Lung RecruitmEnt Assessed by EleCtRical Impedance Tomography (RECRUIT): a multicenter study of COVID-19 acute respiratory distress syndrome. *Am J Respir Crit Care Med* 2023;208:25–38.
2. Chen L, Del Sorbo L, Grieco DL, Junhasavasdikul D, Rittayamai N, Soliman I, *et al.* Potential for lung recruitment estimated by the recruitment-to-inflation ratio in acute respiratory distress syndrome. A clinical trial. *Am J Respir Crit Care Med* 2020;201:178–187.

Renal Replacement Therapy in a World of Constraints: Lessons from the COVID-19 Pandemic

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To the Editor:

We read with interest the insightful article by Mekontso Dessap and coworkers titled "Technical Innovation in Critical Care in a World of Constraints: Lessons from the COVID-19 Pandemic" (1).

Critical care services worldwide have had to cope with constrained conditions during the coronavirus disease (COVID-19) pandemic, particularly because of the limited availability of life-sustaining devices. Mekontso Dessap and colleagues (1) dealt only with the obvious major problems of respiratory failure and mechanical ventilation. However, COVID-19 also causes an excess number of other organ failures, particularly acute kidney injury (AKI), requiring renal replacement therapy (RRT).

Among critically ill patients with COVID-19, 56–76% developed AKI (2), and 14–36% of these patients required RRT (2). This led some teams to face RRT shortages, leading to significant challenges in RRT delivery during the first wave (3). Acute peritoneal dialysis, a modality seldom used in high-income countries, regained interest in this context (4), resulting in outcomes that were similar to those among patients who received extracorporeal RRT (5).

Besides recourse to peritoneal dialysis, a more rational use of extracorporeal RRT can help in coping with such constrained situations. Recent evidence demonstrates that RRT initiation can be safely deferred in many patients with AKI, allowing a major reduction in the number who actually need this treatment (6). In addition to a better selection of patients who need RRT initiation, wiser use of available techniques may allow a substantial increase in the number of patients who can be treated on the same day. Indeed, intermittent hemodialysis may allow the daily treatment of three to four patients with only one machine, in contrast to continuous RRT techniques. This is not the place to compare the relative merits of each technique in normal situations, even if current evidence does not provide any definite clue as to the superiority of one over the other technique for any patient-centered outcome (6). Catastrophic conditions, such as those recently encountered, do not allow subtle discussions on the possible minor advantages of any technique.

A frugal approach to critical care should not be limited to mechanical ventilation. The rationalization of RRT delivery is another

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