

The Mixed Venous Oxygen Saturation Response to Weaning From Mechanical Ventilation

We read with interest the review article, "Critical Illness and Mechanical Ventilation: Effects on the Diaphragm," in the September 2006 issue of RESPIRATORY CARE.¹ In the article it was reported that, "weaning-failure patients develop a relative decrease in oxygen delivery (due to an increase in right and left ventricular afterload) associated with an increase in oxygen extraction, leading to a substantial decrease in mixed venous oxygen saturation," which is a notion based on a landmark study by Jubran et al.² However, this response is actually not observed in all patients who fail to wean. Accordingly, we have recently shown that in a mixed population of patients who fail to wean after several spontaneous breathing trials, 2 distinct patterns of hemodynamic and global tissue oxygenation response are observed.³ In patients who failed weaning without increasing their oxygen consumption ($n = 9$) the increase in oxygen delivery was accompanied by a decrease in oxygen extraction (by $15 \pm 4\%$). In patients who failed ($n = 9$) and increased their oxygen consumption (by $> 10\%$), this increase was met mainly by an increase in oxygen extraction (by $30 \pm 7\%$). Mixed venous oxygen saturation increased (by $2 \pm 1\%$) in the former patients, whereas it decreased (by $20 \pm 5\%$) in the latter. Thus, the fall in mixed venous oxygen saturation is not observed in all patients who fail to wean.

Furthermore, this fall of mixed venous oxygen saturation is not specific for weaning failure. De Backer and colleagues studied relative changes in the cardiac index and oxygen-extraction ratio during successful weaning in patients after cardiac surgery ($n = 52$), cardiac transplantation ($n = 17$), or abdominal aortic surgery ($n = 11$).⁴ The cardiovascular changes were evaluated in 42 patients in whom oxygen consumption (calculated by Fick's equation) increased by more than 10%. Oxygen extraction remained stable in patients after aortic surgery, but increased nonsignificantly after cardiac surgery (from $33.3 \pm 6.1\%$ to $37.3 \pm 6.4\%$), and significantly after cardiac transplantation

(from $25.8 \pm 4.1\%$ to $28.2 \pm 4.0\%$, $p < 0.05$), with corresponding decreases in mixed venous oxygen saturation.⁴

Hence, the cardiovascular response to weaning from mechanical ventilation is complex,^{3,5,6} and the fall in mixed venous oxygen saturation initially described by Jubran et al² is observed in some but not all patients who fail to wean and may also be observed in patients who wean successfully.

Furthermore, in the discussion section of Dr Jubran's review paper,¹ Dr Panitch wondered about the predictability of f/V_T [the ratio of frequency to tidal volume] in patients receiving prolonged mechanical ventilation and the potential use of the tension-time index. We recently found that the f/V_T is the best predictor of weaning outcome in patients who receive < 7 days of mechanical ventilation, whereas the ratio of mean inspiratory airway pressure to peak inspiratory pressure (the major determinant of the tension-time index) is the best predictor of weaning outcome in patients who receive > 7 days of mechanical ventilation.⁷

Theodoros Vassilakopoulos MD
Charis Roussos MD PhD
Spyros Zakynthinos MD

Department of Critical Care and
Pulmonary Services
Evangelismos Hospital
University of Athens Medical School
Athens, Greece

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REFERENCES

1. Jubran A. Critical illness and mechanical ventilation: effects on the diaphragm. *Respir Care* 2006;51(9):1054–1064.
2. Jubran A, Mathru M, Dries D, Tobin MJ. Continuous recordings of mixed venous oxygen saturation during weaning from mechanical ventilation and the ramifications thereof. *Am J Respir Crit Care Med* 1998; 158(6):1763–1769.
3. Zakynthinos S, Routsis C, Vassilakopoulos T, Kaltsas P, Zakynthinos E, Kazi D, Roussos C. Differential cardiovascular responses during weaning failure: effects on tissue oxygenation and lactate. *Intensive Care Med* 2005;31(12):1634–1642.
4. De Backer D, El Haddad P, Preiser JC, Vincent JL. Hemodynamic responses to

successful weaning from mechanical ventilation after cardiovascular surgery. *Intensive Care Med* 2000;26(9):1201–1206.

5. Vassilakopoulos T, Zakynthinos S, Roussos C. Respiratory muscles and weaning failure. *Eur Respir J* 1996;9(11):2383–2400.
6. Richard C, Teboul JL. Weaning failure from cardiovascular origin. *Intensive Care Med* 2005;31(12):1605–1607.
7. Vassilakopoulos T, Routsis C, Sotiropoulou C, Bitsakou C, Stanopoulos I, Roussos C, Zakynthinos S. The combination of the load/force balance and the frequency/tidal volume can predict weaning outcome. *Intensive Care Med* 2006;32(5):684–691.

The author responds:

I thank Dr Vassilakopoulos and colleagues for their interest in my review article.¹ Their comments highlight the complexity of the pathophysiology and hemodynamic responses in patients who fail to wean from mechanical ventilation.

Vassilakopoulos and colleagues point out that not all weaning-failure patients develop a decrease in mixed venous oxygen saturation. Their comments are based on their study,² in which they subdivided weaning-failure patients into 2 groups: (1) those in whom a true increase in oxygen consumption (arbitrarily defined by the investigators as $> 10\%$) occurred between mechanical ventilation and the end of the weaning trial, and (2) those who did not develop such an increase in oxygen consumption. They observed a decrease in mixed venous oxygen saturation only in patients who developed true increases in oxygen consumption; mixed venous oxygen saturation did not change in patients who did not increase oxygen consumption. Whether 2 such distinctive patterns in hemodynamics occur in weaning-failure patients is questionable, since Zakynthinos et al² used calculated (rather than measured) values for oxygen consumption and they categorized patients based on an arbitrarily defined oxygen consumption of 10%. Methodological errors as a result of using derived oxygen consumption measurements have resulted in misinterpretation of numerous studies on oxygen delivery and oxygen utilization by tissues in critically ill patients.^{3–8}

Vassilakopoulos and colleagues refer to the study by De Backer et al⁹ to suggest that a decrease in mixed venous oxygen saturation occurs in patients who successfully wean, but De Backer et al⁹ studied only successfully weaned postoperative patients and purposely excluded weaning-failure patients, so their study focused on hemodynamic changes from positive-pressure ventilation to spontaneous breathing rather than pathophysiology of weaning failure. Like Zakyntinos et al,² they also classified their patients based on a calculated variable rather than a measured variable. Moreover, all patients were receiving various regimens of vasoactive drugs, which may have influenced their results.

I agree with Vassilakopoulos et al that hemodynamic response in weaning-failure patients is highly variable from patient to patient. And a drop in mixed venous oxygen saturation may not occur in every weaning-failure patient. However, despite this variability, weaning-failure patients as a group have lower mixed venous oxygen saturation than do weaning-success patients over the course of a weaning trial. Our data,¹⁰ and those of Zakyntinos et al,² are in agreement that the decrease in mixed venous oxygen saturation in weaning-failure patients is due to a relative decrease in oxygen transport,

combined with an increase in oxygen extraction.

Amal Jubran MD

Division of Pulmonary and
Critical Care Med
Edward Hines Jr Veterans
Affairs Hospital
Loyola University
Hines, Illinois

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REFERENCES

1. Jubran A. Critical illness and mechanical ventilation: effects on the diaphragm. *Respir Care* 2006;51(9):1054–1061.
2. Zakyntinos S, Routsis C, Vassilakopoulos T, Kaltsas P, Zakyntinos E, Kazi D, et al. Differential cardiovascular responses during weaning failure: effects on tissue oxygenation and lactate. *Intensive Care Med* 2005;31(12):1634–1642.
3. Danek SJ, Lynch JP, Weg JG, Dantzker DR. The dependence of oxygen uptake on oxygen delivery in the adult respiratory distress syndrome. *Am Rev Respir Dis* 1980;122(3):387–395.
4. Bihari D, Smithies M, Gimson A, Tinker J. The effects of vasodilation with prostacyclin on oxygen delivery and uptake in critically ill patients. *N Engl J Med* 1987;317(7):397–403.
5. Ronco JJ, Fenwick JC, Tweeddale MG, Wiggs BR, Phang PT, Cooper DJ, et al. Identification of the critical oxygen delivery for anaerobic metabolism in critically ill septic and nonseptic humans. *JAMA* 1993;270(14):1724–1730.
6. Ronco JJ, Fenwick JC, Wiggs BR, Phang PT, Russell JA, Tweeddale MG. Oxygen consumption is independent of increases in oxygen delivery by dobutamine in septic patients who have normal or increased plasma lactate. *Am Rev Respir Dis* 1993;147(1):25–31.
7. Phang PT, Cunningham KF, Ronco JJ, Wiggs BR, Russell JA. Mathematical coupling explains dependence of oxygen consumption on oxygen delivery in ARDS. *Am J Respir Crit Care Med* 1994;150(2):318–323.
8. Hanique G, Dugernier T, Laterre PF, Dougnac A, Roeseler J, Reynaert MS. Significance of pathologic oxygen supply dependency in critically ill patients: comparison between measured and calculated methods. *Intensive Care Med* 1994;20(1):12–18.
9. De Backer D, El Haddad P, Preiser JC, Vincent JL. Hemodynamic responses to successful weaning from mechanical ventilation after cardiovascular surgery. *Intensive Care Med* 2000;26(9):1201–1206.
10. Jubran A, Mathru M, Dries D, Tobin MJ. Continuous recordings of mixed venous oxygen saturation during weaning from mechanical ventilation and the ramifications thereof. *Am J Respir Crit Care Med* 1998;158(6):1763–1769.