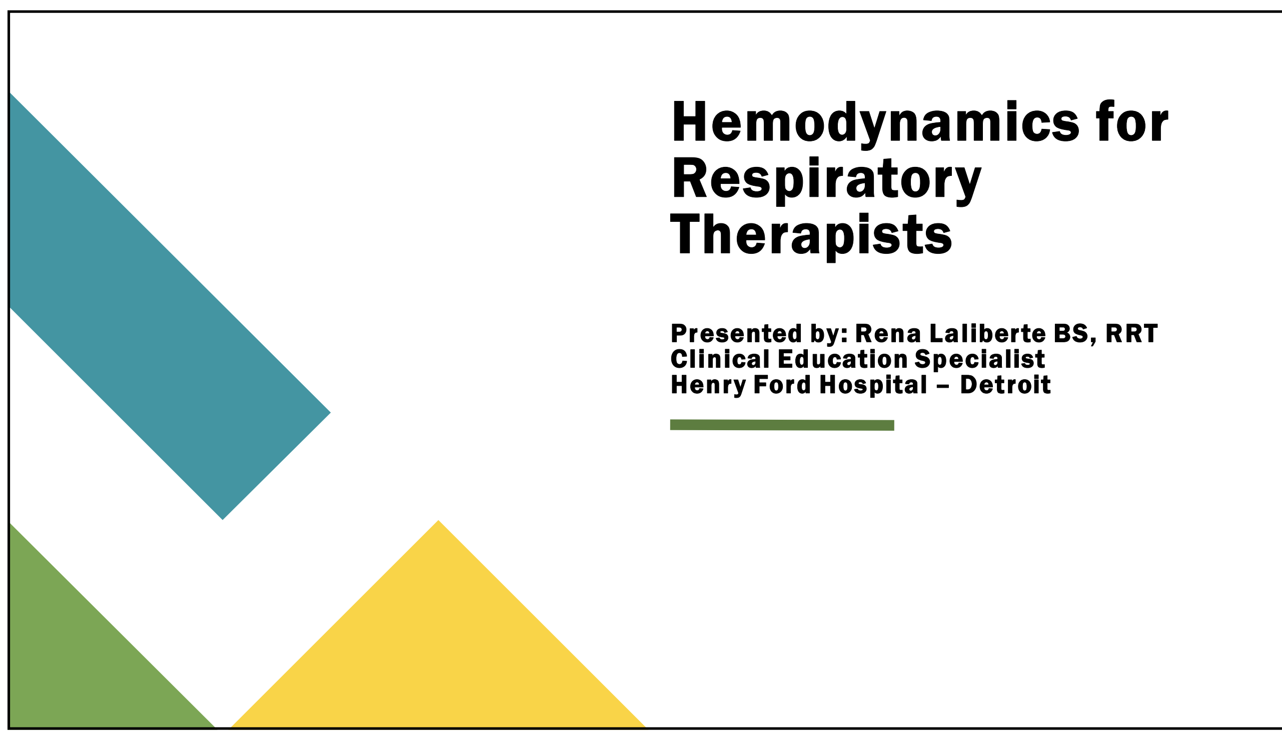


1

Objectives

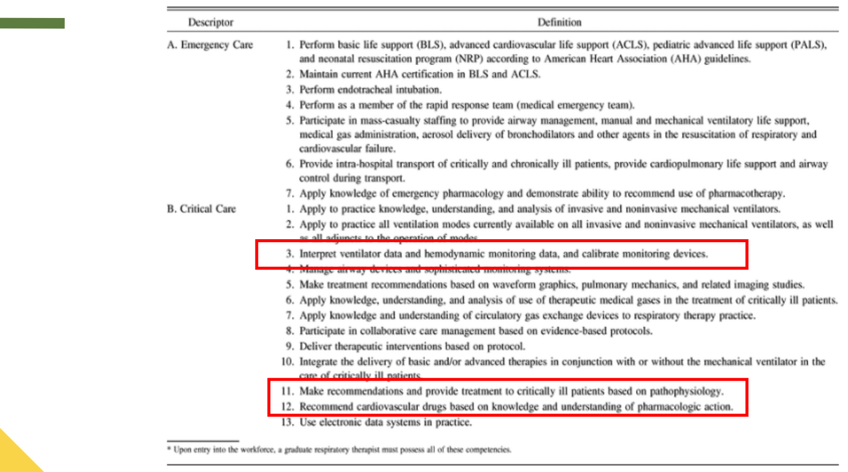
- Review considerations for Respiratory Therapists in 2015 and Beyond
- Discuss cardiovascular issues in respiratory care
- Examine the effects of respiratory indices on hemodynamics during mechanical ventilation

2

Competencies Needed by Graduate Respiratory Therapists in 2015 and Beyond

Thomas A Barnes, David D Gale, Robert M Kacmarek and Woody V Kageler

Respiratory Care May 2010, 55 (5) 601-616;



Descriptor	Definition
A. Emergency Care	1. Perform basic life support (BLS), advanced cardiovascular life support (ACLS), pediatric advanced life support (PALS), and neonatal resuscitation program (NRP) according to American Heart Association (AHA) guidelines.
	2. Maintain current AHA certification in BLS and ACLS.
	3. Perform endotracheal intubation.
	4. Perform as a member of the rapid response team (medical emergency team).
	5. Participate in mass-casualty staffing to provide airway management, manual and mechanical ventilatory life support, medical gas administration, aerosol delivery of bronchodilators and other agents in the resuscitation of respiratory and cardiovascular failure.
	6. Provide intra-hospital transport of critically and chronically ill patients, provide cardiopulmonary life support and airway control during transport.
	7. Apply knowledge of emergency pharmacology and demonstrate ability to recommend use of pharmacotherapy.
B. Critical Care	1. Apply to practice knowledge, understanding, and analysis of invasive and noninvasive mechanical ventilators.
	2. Apply to practice all ventilation modes currently available on all invasive and noninvasive mechanical ventilators, as well as all adjuncts to the operation of modes.
	3. Interpret ventilator data and hemodynamic monitoring data, and calibrate monitoring devices.
	4. Manage airway devices and sophisticated monitoring systems.
	5. Make treatment recommendations based on waveform graphics, pulmonary mechanics, and related imaging studies.
	6. Apply knowledge, understanding, and analysis of use of therapeutic medical gases in the treatment of critically ill patients.
	7. Apply knowledge and understanding of circulatory gas exchange devices to respiratory therapy practice.
	8. Participate in collaborative care management based on evidence-based protocols.
	9. Deliver therapeutic interventions based on protocol.
	10. Integrate the delivery of basic and/or advanced therapies in conjunction with or without the mechanical ventilator in the care of critically ill patients.
	11. Make recommendations and provide treatment to critically ill patients based on pathophysiology.
	12. Recommend cardiovascular drugs based on knowledge and understanding of pharmacologic action.
	13. Use electronic data systems in practice.

* Upon entry into the workforce, a graduate respiratory therapist must possess all of these competencies.

3

Respiratory Therapists 2015 and Beyond

1. Understand Evidence Based Medicine, including the ability to critically read and critique the literature and discuss the meaning of statistical analysis
2. Understanding of pharmacology for all organ systems as well as all drugs delivered via the respiratory system
3. Excellent critical thinking skills
4. Problem solving skills, which are needed to calibrate, operate, and troubleshoot complex technology

4

Respiratory Therapists 2015 and Beyond

- Broad knowledge of various approaches to monitoring, which includes:
  - Laboratory values
  - X ray interpretation
  - CT Scans
  - MRI
  - Bedside monitoring data
    - Must be proficient in the monitoring of hemodynamics and must be able to evaluate pressures, flows and volumes

5

Respiratory Therapists 2015 and Beyond

- In the ICU RT's need a working knowledge of pharmacology that is required: specifically, an understanding of drugs that affect the patient's interaction with the mechanical ventilator.
- This includes agents used to treat cardiovascular dysfunction, tracheobronchial airways, and pulmonary vasculature. This also includes inhaled gases.
- We should also be aware of all sedatives being used on our ICU patients or ancillary administration of drugs.

6

Familiarity with Devices

- Central Lines
- Pulmonary artery catheters
- Arterial Lines
- Sv02 devices
- Intracranial Devices
- As well as their placement sites, which may vary based on the patient.

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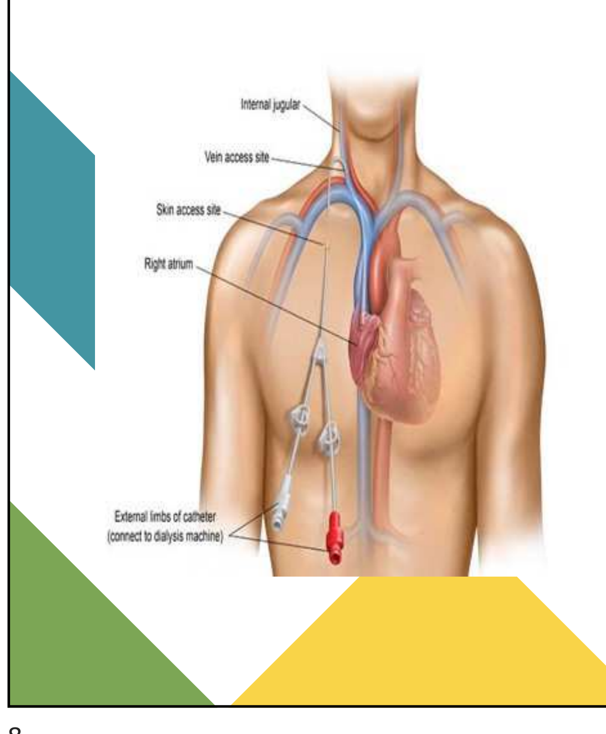


CVP
RV
MAP
PAP
MPAP
PCWP
CO
CI

Hemodynamic values that are measured directly

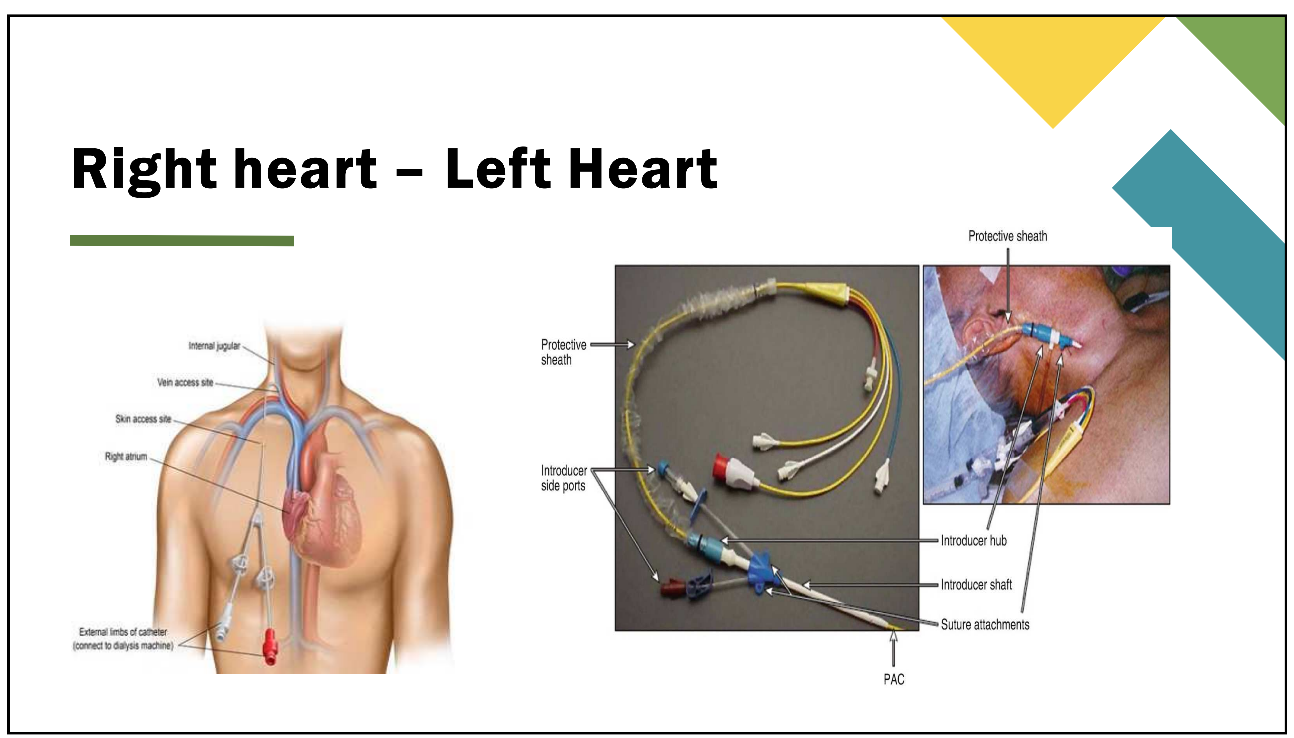
8

Hemodynamic values that are measured indirectly

- Stroke Volume
- Stroke Volume Index
- LV stroke work index
- RV stroke work index
- Pulmonary vascular resistance
- Systemic vascular resistance

9

Right heart – Left Heart



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Medications

- RTs should be familiar with the following:
- Gases/Medications that treat pulmonary hypertension
  - Nitric Oxide administration / Epoprostenol/Prostaglandine E1 etc.
  - Medications for treatment of Cardiac and Blood Pressure issues
  - Vasopressors
  - Inotropes
  - Chronotropes

11

Volume 128, Issue 5, Supplement 2, November 2005, Pages 592S-597S

Cardiovascular Issues in Respiratory Care

Pinsky Michael R. MD, FCCP [a]

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Ventilation can profoundly alter cardiovascular function via complex, conflicting, and often opposite processes. These processes reflect the interaction between myocardial reserve, ventricular pump function, circulating blood volume, blood flow distribution, autonomic tone, endocrinologic responses, lung volume, intrathoracic pressure (ITP), and the surrounding pressures for the remainder of the circulation. Clearly, the final response to ventilatory stress is dependent on the baseline cardiovascular state of the subject.

12

Cardiovascular Issues in Respiratory Care

- Hemodynamic effects of ventilation grouped under four clinically relevant concepts
- 1. Spontaneous ventilation is exercise; critically ill patients may not withstand SV. MV support improves 02 delivery by decreasing 02 consumption. Patients who fail to wean also manifest cardiovascular insufficiency, supplementing support with inotropic therapy may allows patients to wean from MV.
- 2. Changes in lung volume alter autonomic tone and PVR. High lung volumes compress the heart. Hyperinflation also increases PVR and PAP impeding RV ejection. Low lung volumes induce alveolar collapse and hypoxia stimulating pulmonary vasoconstriction. Recruitment maneuvers, PEEP and CPAP may reverse vasoconstriction and lower PAP.

13

Cardiovascular Issues in Respiratory Care

- 3. Spontaneous inspiration and efforts decrease intrathoracic pressure (ITP) diaphragmatic descent increased intra-abdominal pressure, these combined efforts cause RAP inside the thorax to decrease but venous pressure in the abdomen to increase, markedly increasing the pressure gradient for systemic venous return. Furthermore, the greater the decrease in ITP the greater the increase in LV afterload for a constant arterial pressure. MV by abolishing negative swings in ITP, will selectively decrease LV afterload, as long as the increases in lung volume and ITP are small.

14

Cardiovascular Issues in Respiratory Care

- 4. PPV increases ITP. Diaphragmatic descent increases ITP the decrease in the pressure gradient for venous return is less that would otherwise occur if the only change were an increase in RAP. However, in hypovolemic states, PPV can induce profound decreases in venous return. Increases in ITP decrease LV afterload and will augment LV ejection, increased cardiac output, and reduce myocardial myocardial oxygen demand.

15

CHEST Postgraduate Education Corner

CONTEMPORARY REVIEWS IN CRITICAL CARE MEDICINE

Hemodynamic Evaluation and Monitoring in the ICU*

Michael R. Pinsky, MD, FCCP

- Despite options available, most ICU's monitor and display only BP, heart rate and oxygen saturation by pulse oximetry and have for the last 20 years.
- These displays do not drive treatment protocols but rather serve as automated VS signals to trigger further attention.
- It is hard then to validate the utility of monitoring when it is used in this fashion because no hemodynamic monitoring device will improve outcomes unless coupled to a treatment that itself improves outcomes.

16

Hemodynamic Evaluation and Monitoring in the ICU

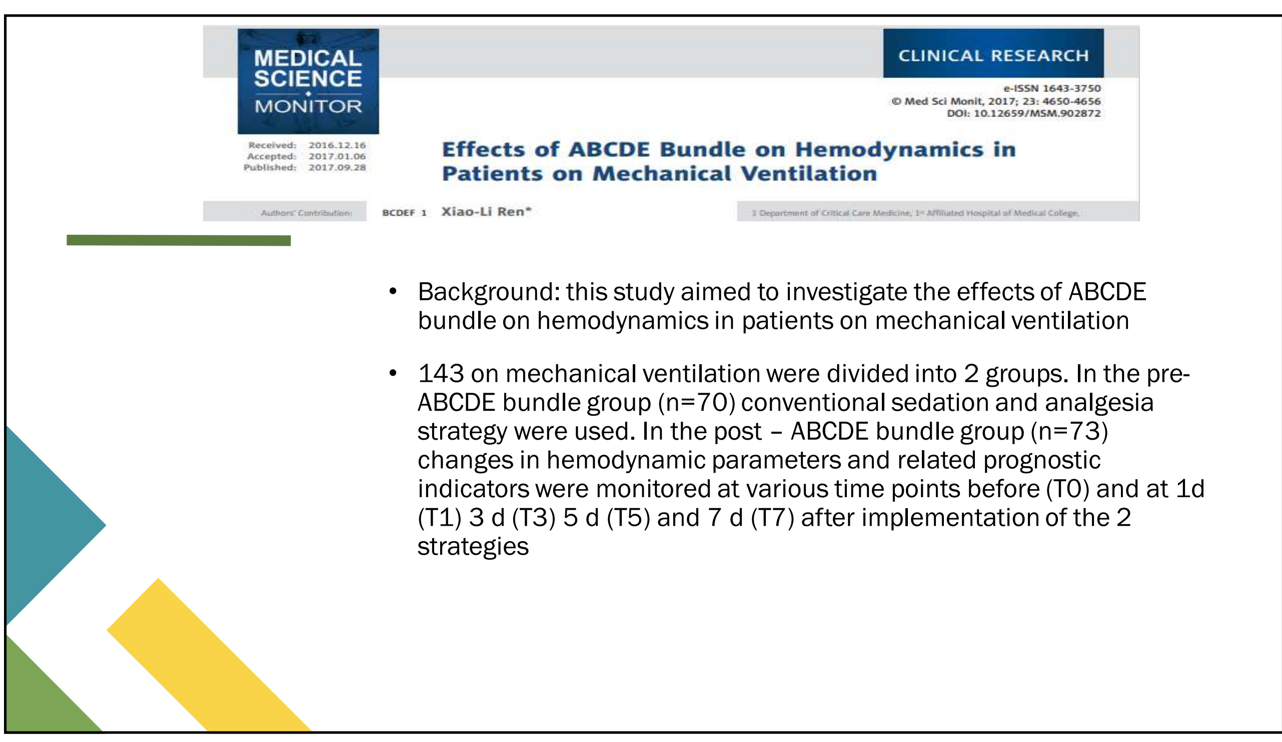
- Obstructive shock represents a blockage of blood flow (R - embolus, hyperinflation, tamponade L-aortic stenosis or dissecting aneurysm)
- R. Ventricular outflow obstruction (pulmonary embolism, hyperinflation)
- Tamponade (pericardial effusion, hyperinflation)
- L. Ventricular outflow obstruction (aortic stenosis, dissecting aortic aneurysm)
- Specific findings can be more subtle, but include decreased LV diastolic compliance, signs of core pulmonale, tricuspid regurgitation.

17

Effects of ABCDE Bundle on Hemodynamics

- Background on ABCDE bundle-
- Based on evidenced based medicine the ABCDE bundle has been used for ICU patients on mechanical ventilation to improve the quality of care and optimize clinical outcomes.
- Specifically, ABC refers to awakening, breathing coordination
- D refers to delirium and monitoring/management
- E refers to early exercise and mobility

18



19

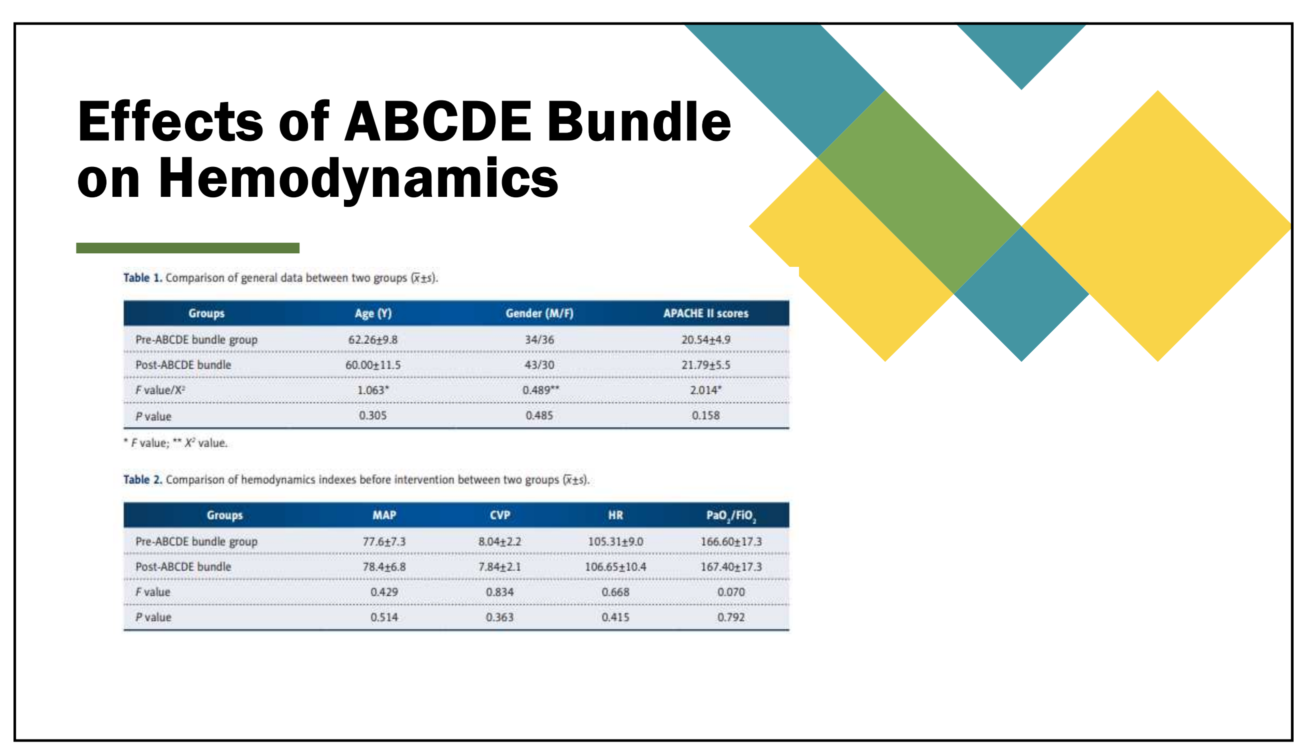
Effects of ABCDE Bundle on Hemodynamics

Most research on ABCDE bundle has focused on the prognosis of patients on MV and prevention of delirium and acquired weakness, but few studies have assessed the effects of hemodynamics .

The hemodynamics index can show pathological and physiological changes and clinical development which could also be applied in diagnosis and therapy in the ICU

Hemodynamics index monitoring is important in discovering causes of disease at the early stage ,

20



Effects of ABCDE Bundle on Hemodynamics

Table 1. Comparison of general data between two groups ($\bar{x}$±s).

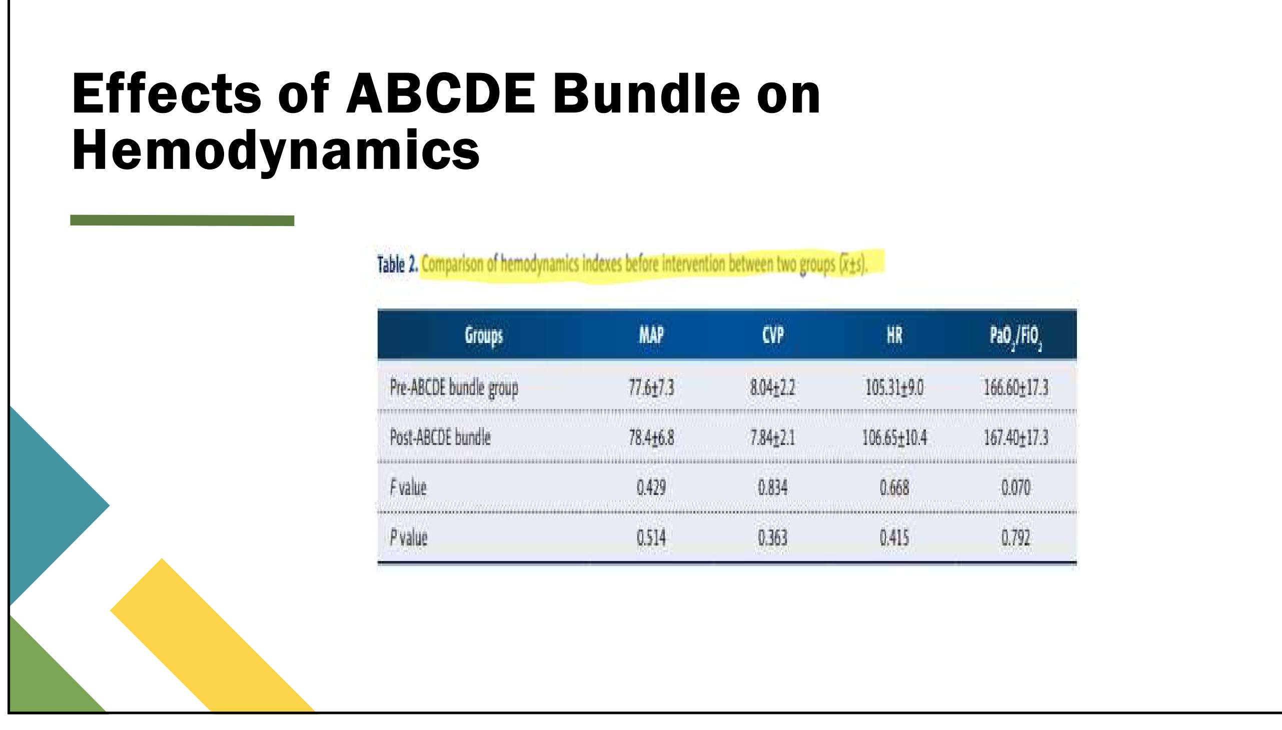
Groups	Age (Y)	Gender (M/F)	APACHE II scores
Pre-ABCDE bundle group	62.26±9.8	34/36	20.54±4.9
Post-ABCDE bundle	60.00±11.5	43/30	21.79±5.5
F value/X^2	1.063*	0.489**	2.014*
P value	0.305	0.485	0.158

* *F* value; ** X^2 value.

Table 2. Comparison of hemodynamics indexes before intervention between two groups ($\bar{x}$±s).

Groups	MAP	CVP	HR	PaO_2/FiO_2
Pre-ABCDE bundle group	77.6±7.3	8.04±2.2	105.31±9.0	166.60±17.3
Post-ABCDE bundle	78.4±6.8	7.84±2.1	106.65±10.4	167.40±17.3
F value	0.429	0.834	0.668	0.070
P value	0.514	0.363	0.415	0.792

21



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22

Effects of ABCDE Bundle on Hemodynamics

Table 3. Dynamic changes of hemodynamics indexes in two groups ($x \pm s$)

Groups	Time	MAP (mmHg)	CVP (cmH_2O)	HR (bpm)	PaO_2/FiO_2 (mmHg)
Pre-ABCDE bundle group	T0	77.6±7.3	8.04±2.2	105.31±9.0	166.6±17.3
	T1	79.6±8.5	8.51±2.9	103.50±7.1	168.8±16.5
	T3	80.0 ± 6.4^{b}	8.37 ± 2.6^{b}	102.70 ± 8.2^{b}	171.3 ± 14.4^{b}
	T5	$82.1 \pm 6.4^{*b}$	$9.54 \pm 3.2^{*}$	$95.91 \pm 7.0^{*b}$	$213.7 \pm 31.3^{*b}$
	T7	$81.4 \pm 6.4^{*b}$	$9.47 \pm 3.2^{*b}$	$90.41 \pm 6.9^{*b}$	$227.3 \pm 25.3^{*b}$
Bundle group	T0	78.4±6.8	7.84±2.1	106.65±10.4	167.4±17.3
	T1	80.3±9.5	8.00±2.9	105.09±8.7	171.8±17.2
	T3	$83.6 \pm 7.7^{*a}$	$8.90 \pm 3.4^{*a}$	$98.46 \pm 7.3^{*a}$	$194.3 \pm 28.1^{*a}$
	T5	$84.5 \pm 7.9^{*a}$	$8.41 \pm 3.1^{*a}$	$93.42 \pm 6.7^{*a}$	$240.2 \pm 39.3^{*a}$
	T7	$83.7 \pm 6.9^{*a}$	$8.72 \pm 3.0^{*a}$	$85.61 \pm 7.2^{*a}$	$257.0 \pm 39.0^{*a}$

Compared with T0: $^{*}P<0.05$; compared with the pre-ABCDE bundle group: $^{a}P<0.05$; compared with the post-ABCDE bundle group: $^{b}P<0.05$; T0 – before intervention; T1 – 1d after MV; T3 – 3d after MV; T5 – 5d after MV; T7 – 7d after MV.

23

Effects of ABCDE Bundle on Hemodynamics

Table 4. Comparison of the dose of sedatives and analgesics between two groups ($x \pm s$).

Groups	n	Sufentanil		Midazolam	
		Total dose (mg)	Average dose (mg/kg·h)	Total dose (mg)	Average dose (mg/kg·h)
Pre-ABCDE bundle group	70	292.1±58.6	0.030±0.007	286.7±58.1	0.029±0.007
Post-ABCDE bundle	73	170.8±73.6	0.018±0.009	164.6±70.4	0.017±0.009
T value		10.860	8.746	11.268	8.430
P value		0.000	0.000	0.000	0.000

Comparison between the pre-ABCDE bundle and post-ABCDE bundle groups: $P<0.05$;

Table 5. Comparison of delirium incidence, 28d survival, mechanical ventilation duration, and length of stay in ICU between two groups ($x \pm s$).

Groups	n	Delirium		28 d survival		Mechanical ventilation duration	Length of stay in ICU
		n	Survival rate (%)	n	Survival rate (%)		
Pre-ABCDE bundle group	70	29	41.4	51	72.9	7.51±3.36	9.76±3.75
Post-ABCDE bundle	73	13	17.8	64	87.7	5.67±3.03	7.47±2.53
T value/X^2			9.611^{**}		4.980^{**}	4.856^{*}	4.435^{*}
P value			0.002		0.026	0.001	0.000

* *T* value; ** X^2 value.

24

Effects of ABCDE Bundle on Hemodynamics

Conclusions

ABCDE bundle can significantly improve the hemodynamics indicators of patients on mechanical ventilation, reduce the dose of the sedatives and analgesics used, and keep the hemodynamics indicators, including MAP, CVP, and HR, at levels beneficial to patients. Finally, according to the patients' response, ABCDE bundle could achieve the optimal therapeutic ends. Based on satisfying the volume state of the tissue perfusion, the ABCDE bundle is not only beneficial to the venous return, cardiac work, but also could protect the other organs, all of which could increase the oxygenation index and improve the circulatory function.

Therefore, application of the hemodynamics therapy mediated targeted therapy strategy is the crucial factor for improving the outcomes of the patients.

25

Experts' opinion on management of hemodynamics in ARDS patients: focus on the effects of mechanical ventilation

A. Vieillard-Baron[1,2,3*], M. Matthay[4], J. L. Teboul[5,6], T. Bein[7], M. Schultz[8], S. Magder[9] and J. J. Marini[10]

- ARDS is frequently associated with hemodynamic instability which appears as the main factor associated with mortality. WHY?
- Shock is driven by pulmonary hypertension, injurious effects of MV on RV function, and associated sepsis
- Hemodynamic effects of ventilation are due to changes in Ppl and changes in TPP.
- TP affects RV afterload, whereas changes in Ppl affect venous return.
- Tidal forces (stress and shear) and PEEP increase PVR in direct proportion to their effects on mean airway pressure (mPaw)
- The injured lung has a reduced capacity to accommodate flowing blood and increases in blood flow accentuate fluid filtration.
- The dynamics of vascular pressure may contribute to VILI
- In order to optimize perfusion, improve gas exchange, and minimize VILI risk, MONITORING HEMODYNAMICS IS IMPORTANT

Intensive Care Med (2016) 42:739–749 DOI 10.1007/s00134-016-4326-3

26

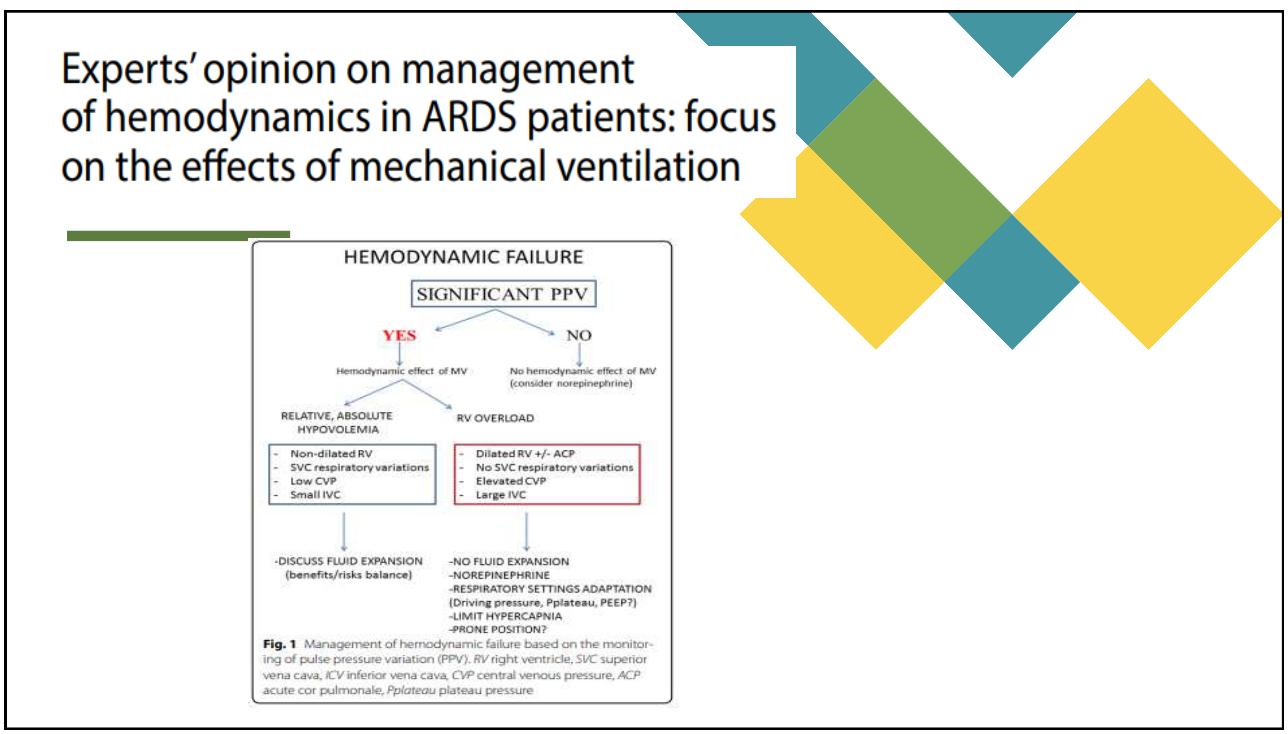

Fig. 1 Management of hemodynamic failure based on the monitoring of pulse pressure variation (PPV). *RV* right ventricle, *SVC* superior vena cava, *ICV* inferior vena cava, *CVP* central venous pressure, *ACP* acute cor pulmonale, *Pplateau* plateau pressure

27

Experts' opinion on management of hemodynamics in ARDS patients: focus on the effects of mechanical ventilation

moderate/severe ARDS
PaO_2/FIO_2
< 150
begin ≤ 7 days

- V_T = 6 ml/kg/PBW
- PEEP ≥ 12 cm H_2O
- prone position
- neuromuscular blockade

PaO_2/FIO_2
< 70 ≥ 3 h
< 100 ≥ 6 h
-MAP ≥ 65 mmHg

PaO_2/FIO_2 > 70
-pH < 7.20 ≥ 6 h
-P_{plat} > 28 cm H_2O ≥ 6 h

-Echo:
sPAP > 40 mmHg,
acute cor pulmonale

NOR ≤ 0.5 µg/kg/min

+ NOR > 0.5 µg/kg/min
+/- severe LV-dysfunction

$ECCO_2$-R

Consider*

Monitoring:
-MAP, ECMO-flow, Echo
-pulse contour analysis (?)
-daily fluid balance
-SvO_2, lactate

avoid
hypovolemia:
-cannula chatter
-NOR ↑
-organ perfusion ↓

avoid
hypervolemia:
-lung edema
-prognosis ↓

hemodynamic management

vv-ECMO

va-ECMO

Fig. 3 Proposed algorithm regarding indications for ECMO/$ECCO_2$R and hemodynamic management during ECMO/$ECCO_2$R in patients with severe ARDS at risk of hemodynamic instability. Readers have to be cautioned that this algorithm was not previously validated. V_T tidal volume, P_{plat} inspiratory plateau pressure, *MAP* mean arterial pressure, *NOR* norepinephrine, SvO_2 central venous oxygen saturation. *Asterisk* as re-emphasized in the text, this is currently not evidence-based data

28

Experts' opinion on management of hemodynamics in ARDS patients: focus on the effects of mechanical ventilation

- In passively ventilated patients in shock, monitoring signals linked to the tidal cycle and ventricular loading help predict preload and afterload dependence of the right ventricle.
- Interventions directed toward improving compensation of the compromised RV include reduction of unnecessary systemic oxygen demand, optimized fluid resuscitation, appropriate lung recruitment, prone positioning, avoidance of acidosis, maintenance of oxygenation, and well-selected pharmacologic agents.
- (cont. next slide)

29

Experts' opinion on management of hemodynamics in ARDS patients: focus on the effects of mechanical ventilation

- In severe cases, varied options for extracorporeal gas exchange can be deployed to reduce ventilatory and cardiac workloads while compensating for impaired oxygenation. Once shock is resolved, a fluid conservative protocol may reduce the duration of positive pressure ventilation.
- Successfully managing the complex hemodynamics of the ventilated patient with ARDS is key to patient survival. Doing so in this setting requires guidance from a deep understanding of the underlying principles of cardiopulmonary physiology, rendering it difficult to enumerate definitive, specific, and universally applicable guidelines.

30

Hemodynamic Implications of Prone Positioning in Patients with ARDS

Christopher Lai*, Xavier Monnet and Jean-Louis Teboul

- .....lung recruitment also permits a decrease in atelectrauma, reduction in the transpulmonary driving pressure, and increase in lung compliance. Hence, prone positioning may limit the mechanical power and might thus prevent ventilator-induced lung injury (VILI). In addition to the effects on oxygenation and respiratory mechanics, prone positioning induces some hemodynamic effects, which may also be beneficial. In this article, we review how prone positioning can exert those favorable cardiovascular effects. Moreover, prone position sessions are at least 16h long, and even sometimes extended up to 39h. During such a long time of period, the question of administering fluid therapy may arise. This paper explores how preload responsiveness could be detected to guide fluid therapy in patients in the prone position.

Lai et al. Critical Care (2023) 27:98
https://doi.org/10.1186/s13054-023-04369-x

31

Hemodynamic Implications of Prone Positioning in Patients with ARDS

Christopher Lai*, Xavier Monnet and Jean-Louis Teboul

- Prone positioning increases the intra-abdominal pressure (IAP) This may cause two distinct effects on venous return. On the one hand, prone positioning increases Pms (mean systemic pressure) and central venous pressure (CVP) to a lesser extent, resulting in an increase in the pressure gradient of venous return These effects are due to lowering the trunk from the semi-recumbent position to the strict supine horizontal position, secondary to a passive shift of blood from the splanchnic compartment to the heart, as occurs during passive leg raising; and to transferring the patient from the strict supine to the prone position, an effect that is predominant.

(Splanchnic is usually used to describe organs in the abdominal cavity)

32

Hemodynamic Implications of Prone Positioning in Patients with ARDS

Christopher Lai*, Xavier Monnet and Jean-Louis Teboul

- In ARDS, RV dysfunction is not rare with a prevalence of 10 to 30% in large observational studies. Severe RV dysfunction is associated with an increase in mortality.
- The cause of RV dysfunction is the increase in RV afterload secondary to an increase in PVR.
- PVR increase can be due to hypoxic vasoconstriction, inflammatory mediators, microthrombi formation, or hemodynamic effects of mech. ventilation.

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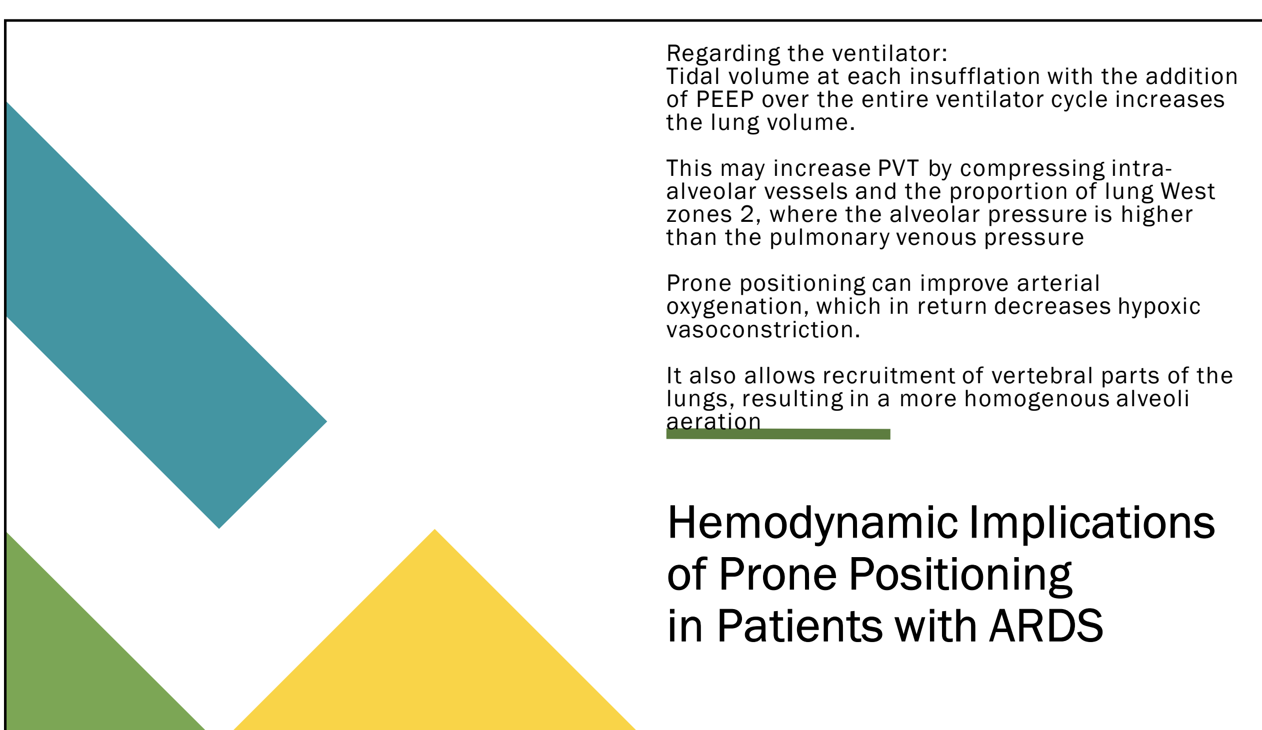

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Hemodynamic Implications of Prone Positioning in Patients with ARDS

Christopher Lai[*], Xavier Monnet and Jean-Louis Teboul

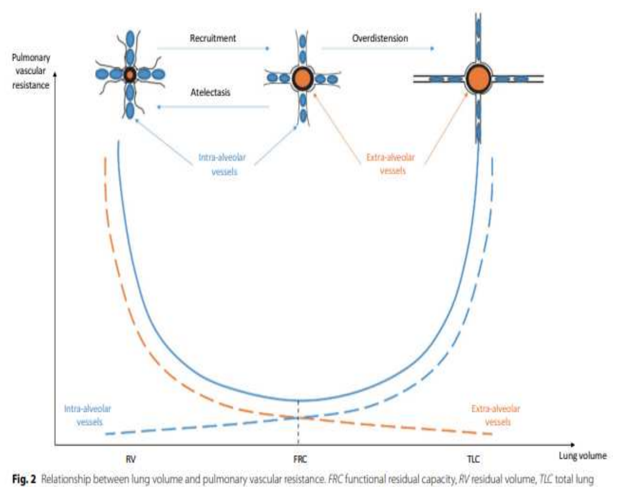

Fig. 2 Relationship between lung volume and pulmonary vascular resistance. *FRC* functional residual capacity, *RV* residual volume, *TLC* total lung capacity

35

Hemodynamic Implications of Prone Positioning in Patients with ARDS

Detecting fluid responsiveness in Patients in the Prone Position-

The risk/benefit ratio of fluid therapy should thus be carefully evaluated before any fluid administration, and it is therefore essential to assess preload responsiveness . In this regard, several dynamic indices or tests can be performed. These can be used in the prone position during ARDS

Trendelenburg Maneuver – Passive leg raise

End-Expiratory Occlusion Test

Pulse Pressure Variation

Tidal Volume Challenge

Mini Fluid Challenge

36

In Conclusion

- Respiratory Therapist need to have a strong understand of the relationship between mechanical ventilation and hemodynamics in the critically ill patient
- Most ICU monitors display data that causes us to act reactively to situations and not proactively
- Monitoring Hemodynamic values gives the clinicians an opportunity to react in a proactive manner that is proven to improve mortality rates in our ICU patients
- More research needs to be done to determine the best ways to both monitor and effectively treat our patients

37

Time for Questions!

38