Overview of ARDS Ventilator Management Strategies

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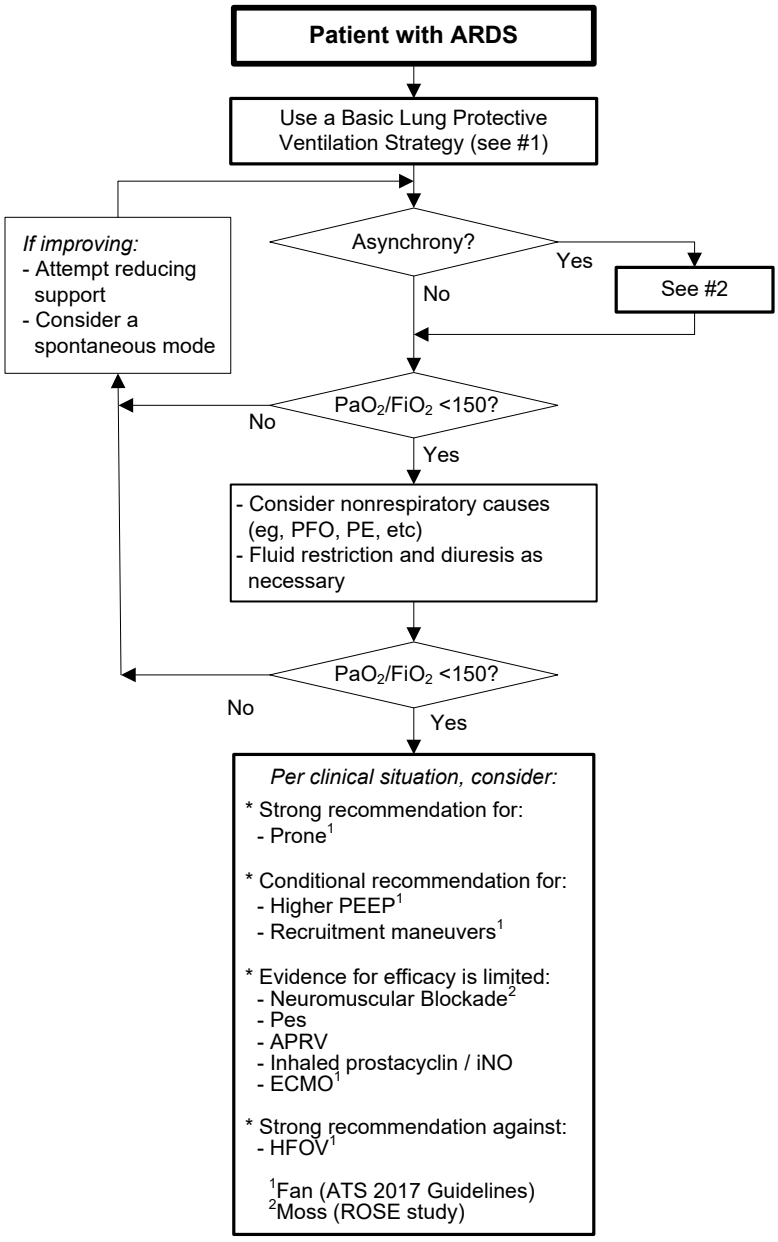

1: Basic Lung Protective Ventilation

- ARDS Network ventilation strategy:
  a. Use VCV or PCV, targeting VT 6 mL/kg PBW
  b. Maintain Pplat ≤30 cm H_2O
     - Reduce VT to 5 or 4 mL/kg if necessary
  c. PEEP/FiO_2 per table (see bottom of page)
- Consider maintaining driving pressure ≤12-15 cm H_2O
- If consolidation is asymmetrical, consider placing 'good lung' in dependent position

2: Patient-Ventilator Asynchrony

* Consider minor ventilator adjustments (eg, flow rate & pattern, inspiratory pause)
* Assess potential to treat with pharmacologic agents (eg. sedation, NMB), especially in pt with severe ARDS and strong respiratory drive (double-trigger)
* For double-triggering, consider increasing VT 1 mL/kg (max 8 mL/kg), provided Pplat ≤30 cm H_2O
* For flow asynchrony, consider a variable flow pressure breath mode of ventilation:
  - Volume targeted PC (PRVC, VC+, Autoflow)
  - Pressure control, pressure support

Prone Positioning

* Consider after initial 12-24 hrs of stabilization
* Use 16 hr/day (generally 4 pm to 10 am)
* Discontinue when:
  - Instability in prone position
  - Supine x 4 hr, PaO_2/FiO_2 >150 on FiO_2 ≤0.60 & PEEP ≤10

Higher PEEP

* For pts with PaO_2/FiO_2 <150, consider higher PEEP table

Recruitment Maneuvers

* Consider for pts with clear de-recruitment, negative Ptp or PaO_2/FiO_2 <150
* Recommend PCV with: 1) 40/20-25 for 1-3 min (as tolerated) or 2) delta-P of 15 and increase PEEP by 5 up to PIP of 40
* If CPAP method used, limit to 15-30 seconds
* Provider should be at bedside if pressures >40 cm H2O used

Neuromuscular Blockade

* No benefit of routine use of NMB in moderate-severe ARDS.
* Consider use if significant asynchrony and concern for VILI.

Esophageal Pressure (Pes) Guided Therapy

* Informs of transpulmonary end-inspiratory (Ptp-plat) and end-expiratory (Ptp-PEEP) pressures
* Requires AVEA ventilator & placement of Pes catheter

Airway Pressure Release Ventilation (APRV)

* Increases Pmean with lower Pplat; lacks outcomes benefit
* Concern for P-SILI in pt with strong respiratory drive

Inhaled Nitric Oxide (iNO)

* Start at 10 ppm
* If positive response (improved oxygenation) or brought in by Survival Flight:
  - Maintain at 10 ppm and reduce FiO_2 down to 0.8, then titrate iNO down, or consider Veletri or iloprost, per Respiratory Care policy
* If no response, discuss with team to consider stopping

NOTE: *iNO is a very costly drug compared to alternatives*

Extracorporal Membrane Oxygenation (ECMO)

* Absolute contraindications: irreversible pulmonary process
* Evaluate, but lower survival if on vent 7-10 days pre-ECMO
* Consider if: PaO_2/FiO_2 <50 x3 hrs or <80 x6 hrs, or pH <7.25 w/ $PaCO_2$ >60 x6 hrs

High Frequency Oscillatory Ventilation (HFOV)

* Strong recommendation against routine use; may have benefit if PaO_2/FiO_2 <64; goal is to increase Pmean

FiO_2/PEEP Tables

Lower PEEP/Higher FiO2 table

Step:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
FiO2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.7	0.8	0.9	0.9	0.9	1.0	1.0	1.0	1.0
PEEP	5	5	8	8	10	10	10	12	14	14	14	16	18	18	20	22	24

Higher PEEP/ Lower FiO2 table (from ROSE study)

Step:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
FiO2	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.6	0.7	0.8	0.8	0.9	1.0	1.0
PEEP	5	5	8	10	12	14	16	16	18	20	20	20	20	22	22	22	24

Consider Lower PEEP for patients with low PEEP-responsiveness potential (ie, P/F ≥150); Higher PEEP if higher PEEP-responsiveness potential (P/F <150) or BMI >35

See page 2 for general comments & recommended reading

Updated: 1/6/20

GENERAL COMMENT

Low VT and minimizing Pplat is the only ventilation strategy with a high level of evidence of mortality benefit in ARDS. Therefore, a lung protective ventilation strategy (LPVS) following the ARDS Network strategy (using pressure or volume ventilation) to limit VT (target 6 mL/kg; reduce to 5 or 4 mL/kg for high Pplat, 7 or 8 mL/kg for double-triggering) and Pplat (≤30 cm H2O) should be the initial and primary strategy for all ARDS patients.

RECOMMENDED READING

Guidelines or Reviews on ARDS Management;

1. Fan E, et al. Am J Respir Crit Care Med 2017;195:1253-1263 [ATS CPG on mechanical ventilation in ARDS]
2. Fan E, et al. JAMA 2018;319:698-710 [Update on ARDS management, contains flow diagram]
3. Matthay MA, et al. Nat Rev Dis Primers 2019;5(1):18 [Review of ARDS, including management]

Setting VT:

* Standard is targeting 6 mL/kg PBW & limit Pplat ≤30 cm H_2O; drive pressure (ie, keep <12-15) may be more important than VT or Pplat

1. The ARDS Network. NEJM 2000; 342(19):1301-1308 [Pivotal ARDS RCT, 861 pts, reduced mortality with 6 mL/kg IBW & Pplat ≤30, is current standard of care]
2. Amato MBP, et al. NEJM 2015;372:747-755 [Secondary analysis of 9 RCTs showing that drive pressure is strongly associated with survival, VT and Pplat were not]
3. Sahetya SK, et al. Am J Respir Crit Care Med 2017;196:1519-1525 [Review on VT selection in ARDS, includes transpulmonary pressure, driving-P, lung strain, etc]

PEEP

* For most pts the Lower PEEP table should be used. For pts with ARDS and P/F <150 and/or those with high Ppl, the Higher PEEP table should be considered

1. Briel M, et al. JAMA 2010; 303:865-873 [Patient-level meta-analysis; higher PEEP associated with improved mortality in subgroup of patients with PaO_2/FiO_2 <200 (moderate & severe ARDS), suggested harm of high PEEP in mild ARDS (PaO_2/FiO_2 >200]
2. Maiolo G, et al. Am J Respir Crit Care Med 2018;197:1586-1595 [Majority of ARDS is moderate (PaO_2/FiO_2 101-200); using PaO_2/FiO_2 of 150, study suggests that 150-200 is similar to mild ARDS and <150 like severe ARDS. Provides evidence for using higher PEEP, as well as prone and NMBA in those with PaO_2/FiO_2 <150]
3. Chiumello D, et al. Crit Care Med 2014;42:252-264 [Cross-over on 51 ARDS pts of 4 PEEP methods; only High PEEP table (LOV) provided PEEP proportional to degree of lung recruitment (vs Pes/Ptp, stress index, EXPRESS)]

Prone Positioning (PP)

* PP improves respiratory mechanics and hemodynamics which improve both oxygenation and RV function; is associated with lower inflammatory mediator levels.

1. Guerin C, et al. N Engl J Med 2013; 368:2159-2168 [RCT, demonstrated reduced mortality in ARDS patients with PaO_2/FiO_2 <150; PP >16 hrs/day]
2. Beitler JR, et al. Intensive Care Med 2014;40:332-341 [Meta-analysis; suggests that when studies stratified by VT size, PP associated with reduced mortality in low VT studies (≤8 mL/kg PBW at baseline)]
3. Dickenson S, Park PK, Napolitano LM. Crit Care Clin 2011; 27:511-523 [Review; describes UM method of prone positioning]

Esophageal Pressure (Pes) Monitoring

* Pes and transpulmonary pressure (Ptp) monitoring helps set PEEP to a positive end-expiratory Ptp and allows assessment of end-inspiratory Ptp vs absolute Pplat

1. Talmor D, et al. NEJM 2008; 359:2095-2104 [Small RCT, improved oxygenation and compliance in Pes-guided PEEP group; underpowered for mortality]
2. Mauri T, et al. Intensive Care Med 2016;42:1360-1373 [Review covering important issues using esophageal manometry]
3. Beitler R, et al. JAMA 2019; 321:846-857 [EPVent2 RCT; 200 mod-severe ARDS pts; no outcome differences between Pes-guided PEEP vs High PEEP strategy]

Recruitment Maneuvers (RM)

* Reserved for pts with clear de-recruitment, negative Ptp or P/F <150. A PC RM may be better tolerated than CPAP. Use with caution and NOT routinely on all pts.

1. Hess D. Respir Care 2015;60:1688-1704 [Review of recruitment maneuvers and PEEP titration]
2. Goligher EC, et al. Ann Am Thorac Soc 2017;14 (Suppl 4):S304-S311 [Meta-analysis (6 RCT, 1423 pt); RM associated with mortality benefit, improved oxygenation, less use of rescue therapy, no increase in barotrauma or hemodynamic compromise]
3. Cavalcanti B. JAMA 2017;318:1335-1345 [ART open lung (OL) RCT (RM of 60/45, changed to 50/35 after 2 cardiac arrests; decremental PEEP begin at 23); OL associated with higher 28-d mortality (55.3 vs 49.3%), increased pneumothorax requiring drainage and barotrauma, fewer VFD's; no diff in ICU or hospital mortality]
4. Bhattacharjee S, et al. J Intensive Care 2018;6:35 [Meta-analysis that includes recent ART study; concludes no mortality or duration (ICU, hospital) benefit]

Neuromuscular Blockade (NMB)

* Although Papazian suggests benefit for ARDS pts with P/F <150, ROSE showed no benefit of NMB when high PEEP used

1. Papazian L, et al. NEJM 2010; 363:1107-1116 [ACURASYS RCT, showed improved survival in group given NMB (cisatricurium) for first 48 hr of management, without increasing muscle weakness; used low PEEP strategy in both groups and heavy sedation in control group]
2. Moss M, et al. NEJM 2019; 380:1997-2008 [ROSE RCT showed no difference in 90-d mortality; used high PEEP in both groups and light sedation in control group]

Airway Pressure Release Ventilation

* Other than Zhao, over 15 RCTs have NOT shown superiority of APRV vs conventional MV. Concern exists about strong resp drive and P-SILI in severe ARDS.

1. Kollish-Singule, et al. Eur Respir Rev 2019;28:180126 [Describes current time-controlled adaptive ventilation (TCAV) method of applying APRV]
2. Zhou Y, et al. Intensive Care Med 2017;43:1648-1659 [RCT (138 ARDS pts); early application of APRV associated with improved oxygenation and respiratory mechanics, decreased Pplat and reduced duration of ventilation and ICU stay; trend toward lower ICU mortality (19.7 vs 34.3%, p=0.053)]
3. Carsetti A, et al. Ann Intensive Care 2019;9:44 [Meta-analysis of 5 RCTs; suggests improvement in VFD and mortality, cautions results due to low quality of evidence and patient heterogeneity]
4. Yoshida T, et al. Am J Respir Crit Care Med 2016:195:985-992 [Review of spont breathing, concern of high respiratory drive & excessive transpulmonary pressure]

Inhaled Nitric Oxide and Inhaled Prostacyclin

* iNO improves oxygenation, reduces shunt thru PFO, helps safe transport to UM, no mortality benefit, is associated with AKI, costly (>$3,500/day not reimbursed)

1. Puri N, Dellinger RP. Crit Care Clin 2011; 27:561-587 [Review of iNO and inhaled prostacyclin in ARDS]
2. Afshari A, et al. Anesth Analg 2011; 112:1411-1421 [Meta-analysis of iNO; iNO improved oxygenation, no mortality benefit, may cause renal damage]

ECMO

* Rescue therapy for severe hypoxemic RF (ARDS w/ P/F <60 on >80% O2) after medical and MV optimized (incl NMB, PEEP, fluid/HD). Consider early consult.

1. Peek GJ, et al. Lancet 2009; 374:1351-1361 [CESAR RCT, suggests transfer to ECMO center for care is associated with improved outcome]
2. Park PK, Napolitano LM, Bartlett RH. Crit Care Clin 2011; 27:627-646 [Review of ECMO in ARDS]
3. Combes A, et al. NEJM 2018; 378:1965-1975 [EOLIA RCT; inclusion: P/F <50 x3 hrs, or <80 x6 hrs, or pH <7.25 w/ $PaCO_2$ >60 x6 hrs; lower trend in 60-d mortality w/ECMO (35 vs 46% (RR 0.76; 95% CI 0.55 to 1.04, p=0.09)); crossover to ECMO in 28% of control, had higher mortality (57%)]

HFOV

* Harmful in mild and moderate ARDS; may be beneficial in very severe (P/F<64) ARDS

1. Ferguson ND, et al. N Engl J Med 2013; 368(9):795-805 [OSCILLATE RCT of 548 severe ARDS pts; mortality for HFOV=47%, control=35%]
2. Young D, et al. N Engl J Med 2013; 368(9):806-813 [OSCAR RCT of 795 severe ARDS patients; no mortality difference (41.7 vs 41.1%)]
3. Meade MO, et al. Am J Respir Crit Care Med 2017;196:727-733 [Patient-level meta-analysis (4 RCT, 1552 pt); HFOV increases mortality for most ARDS patients, may improve survival in patients with severe hypoxemia (ie PaO_2/FiO_2 <64); barotrauma higher with HFOV]