

Guidelines for Acute Respiratory Failure

Key Document code:	WAHT-KD-022
Key Document Owner:	Gareth Sellors
Approved by:	<i>Intensive Care Forum</i>
Date of Approval:	<i>21st February 2018</i>
Date of review:	<i>8th October 2021</i>

Key Amendments

Date	Amendment	Approved by
8 th October 2019	Document extended with no changes as part of Disease Management section in critical care	Dr Nick Cowley/Dr Andy Burtenshaw
13 th March 2020	Update to guide management of COVID-19 patients	Dr Nick Cowley/Dr Andy Burtenshaw

Authors: Mark Griffiths & Gavin Perkins

Modified for use within Worcestershire Acute Hospitals NHS Trust by Dr G P Sellors and Dr a Burtenshaw

RECOMMENDATIONS FROM FACULTY OF INTENSIVE CARE MEDICINE

Authors: Mark Griffiths & Gavin Perkins

Local interpretation: by Dr G P Sellors and Dr A Burtenshaw

- 1) All patients with, or at risk of, acute respiratory failure (ARF) requiring mechanical ventilation should be subjected to a lung protective ventilation strategy using low tidal volumes and airway pressures.

Charts of predicted body weight and ventilator volume range are given at Appendix 1. These charts are attached to the Drager Evita ventilators used throughout the county.

- 2) Patients with moderate to severe ARDS may benefit from the application of high positive end expiratory pressure (PEEP) and from prone positioning for at least 12 hours per day.
- 3) The use of neuromuscular blocking agents in patients with ARDS for the first 48 hours of mechanical ventilation may improve outcome by mitigating ventilator-patient dyssynchrony and thereby ventilator associated lung injury.
- 4) Patients with severe but potentially reversible ARF who cannot achieve adequate gas exchange with protective ventilatory settings, should be discussed with the Heartlink ECMO Centre at Glenfield Hospital, Leicester on telephone number **0300 300 3200**.
- 5) The role of extra-corporeal carbon dioxide removal (ECCO₂R) in patients with ARF has not yet been defined, but this support may help to mitigate the adverse effects of

mechanical ventilation in patients with ARDS and obstructive airways diseases (e.g. asthma and chronic obstructive pulmonary disease [COPD]).

WRH ICCU has considerable clinical experience with ECCO₂R in the context of patients with potentially reversible hypercarbic respiratory failure. The use of ECCO₂R within Worcestershire Acute Hospitals NHS Trust is dealt with in a separate guideline.

- 6) Within Worcestershire, rescue plans for refractory hypoxaemia include recruitment manoeuvres, airway pressure release ventilation (APRV) and inhaled prostacyclin. It is acknowledged that these strategies do not improve the outcome of unselected patients with ARDS.

Following the ICM Forum on the 6th May 2015 HFOV is no longer available within the Worcestershire Intensive Care Units.

- 7) Non-invasive ventilation has an established role in providing respiratory support for patients with acute exacerbations of COPD and early ARDS.
- 8) An active fluid management strategy targeting neutral or negative fluid balance may benefit respiratory recovery in patients with ARDS without compromising the function of other organs.

BACKGROUND

ARF has multiple causes, which may affect the lungs directly (e.g. pneumonia and COPD) or indirectly as part of the multi-organ dysfunction syndrome (e.g. sepsis syndromes). Treatment depends on the underlying causes, but because these may not be immediately obvious, a robust diagnostic approach is required.

In the absence of disease-modifying therapies for ARF, the mainstay of ARF management is to provide respiratory and other organ support whilst causing minimal harm.

The Berlin definition for ARDS distinguishes ARDS into mild, moderate and severe categories on the basis of the severity of impairment of oxygenation (PaO₂:FiO₂ ratio of <300, <200 and <100 mm Hg respectively)¹.

Ventilatory strategies

Meta-analysis of 20 observational studies and control groups from randomised controlled trials which included 2,822 participants at risk of ARDS suggests that patients at risk of ARDS undergoing surgery or being ventilated in the intensive care unit have a lower risk of progression to ARDS and a reduced mortality rate if they receive protective ventilation strategies².

Meta-analysis of six randomised controlled trials involving 1,297 patients showed that the use of protective ventilation in patients with ARDS reduces early (28-day) mortality³.

The use of high levels of PEEP in patients with ARDS has been evaluated in seven randomised trials (2,565 participants).

Compared to standard levels of PEEP, high PEEP improves oxygenation but has no effect on mortality or the risk of barotrauma⁴. An individual patient data meta-analysis from three of these trials suggests that patients with moderate or severe ARDS (P:F ratio < 200 mm Hg) may benefit from the application of higher levels of PEEP⁵.

High-frequency-oscillation ventilation has been subject to six randomised controlled trials which enrolled 1,608 patients with ARDS.⁶ Meta-analysis of the results of these trials showed that although HFOV improves oxygenation and does not seem to increase the risk of barotrauma or hypotension, it does not improve survival.

Non-ventilatory strategies

Pharmacological interventions evaluated to date have either had no overall effect (e.g. steroids) or have been shown to be harmful (e.g. beta agonists), and should not be used routinely.

Risk factors for the development of ARDS amongst patients at risk include blood transfusion, fluid overload and inappropriate initial antibiotic therapy. Careful consideration of the risks and benefits of these treatments should be considered on an individual patient basis.

For patients with established ARDS, the use of prone positioning has been evaluated in nine RCTs with 2,242 patients⁷. Prone positioning improved mortality, particularly in patients with severe ARDS. The effects were more pronounced when the duration of time spent in the prone position exceeded 12 hours.

A multi-centre randomised controlled trial evaluating the use of 48-hours neuromuscular blockade in patients with moderate to severe ARDS (P:F ratio < 150 mm Hg) improved mortality, increased ventilator and organ-failure free days, and reduced bio-trauma without any difference in ICU acquired paresis⁸.

A randomised trial of a conservative fluid strategy in 1,001 patients with established ARDS who did not have evidence of tissue hypoperfusion, led to fewer days of mechanical ventilation and reduced length of ICU stay, without altering the incidence of renal failure or mortality rates⁹.

Referral of patients with potentially reversible, severe ARDS to a regional ECMO centre has been shown to improve mortality and is cost-effective¹⁰. A propensity-matched analysis of patients in the UK with severe ARDS due to H1N1 showed improved mortality amongst patients referred and transferred to a regional ECMO centre¹⁰. After the H1N1 2009 influenza pandemic, a network of five ECMO centres was commissioned to provide retrieval of, and advanced care for, patients with severe ARDS and ARF in England and Wales.

The mortality rate of ARDS remains at approximately 40% for unselected populations, although that of the control groups of multi-centre studies has decreased progressively to between 20-30%.

Chronic respiratory failure is a rare consequence of ARDS, but neuromuscular and psychological after-effects are common and are reflected in high levels of unemployment in survivors after hospital discharge¹¹.

Facilities to support rehabilitation during the recovery phase are recommended, as is follow-up in a specialist out-patient clinic after hospital discharge.

REFERENCES FOR FICM STANDARDS

1. Ferguson ND, Fan E, Camporota L, et al. 'The Berlin definition of ARDS: an expanded rationale, justification, and supplementary material'. *Intensive Care Med* 2012; 38(10):1573-82.
2. Serpa Neto A, Cardoso SO, Manetta JA, et al. 'Association between use of lung-protective ventilation with lower tidal volumes and clinical outcomes among patients without acute respiratory distress syndrome: a meta-analysis'. *JAMA* 2012; 308(16):1651-9.
3. Petrucci N, De Feo C. 'Lung protective ventilation strategy for the acute respiratory distress syndrome'. *Cochrane Database Syst Rev* 2013; 2:CD003844.
4. Santa Cruz R, Rojas JI, Nervi R, et al. 'High versus low positive end-expiratory pressure (PEEP) levels for mechanically ventilated adult patients with acute lung injury and acute respiratory distress syndrome'. *Cochrane Database Syst Rev* 2013; 6:CD009098.
5. Briel M, Meade M, Mercat A, et al. 'Higher vs lower positive end-expiratory pressure in patients with acute lung injury and acute respiratory distress syndrome: systematic review and meta-analysis'. *JAMA* 2010; 303(9):865-73.
6. Gu XL, Wu GN, Yao YW, et al. 'Is high-frequency oscillatory ventilation more effective and safer than conventional protective ventilation in adult acute respiratory distress syndrome patients? A metaanalysis of randomized controlled trials'. *Crit Care* 2014; 18(3):R111.
7. Hu SL, He HL, Pan C, et al. 'The effect of prone positioning on mortality in patients with acute respiratory distress syndrome: a meta-analysis of randomized controlled trials'. *Crit Care* 2014; 18(3):R109.
8. Papazian L, Forel JM, Gacouin A, et al. 'Neuromuscular blockers in early acute respiratory distress syndrome'. *N Engl J Med* 2010; 363(12):1107-16.
9. Wiedemann HP, Wheeler AP, Bernard GR, et al. 'National Heart, Lung, and Blood Institute Acute Respiratory Distress Syndrome (ARDS) Clinical Trials Network. Comparison of two fluid-management strategies in acute lung injury'. *N Engl J Med*. 2006; 354:2564–2575.
10. Noah MA, Peek GJ, Finney SJ, et al. 'Referral to an extracorporeal membrane oxygenation center and mortality among patients with severe 2009 influenza A(H1N1)'. *JAMA* 2011; 306(15):1659-68.
11. Herridge MS, Tansey CM, Matte A, et al. 'Functional disability 5 years after acute respiratory distress syndrome'. *N Engl J Med* 2011 364(14):1293-304.

AIRWAY PRESSURE RELEASE VENTILATION

Definition:

APRV is a time cycled, pressure controlled mode of ventilation for spontaneously ventilating patients. It is characterized by relatively long periods of continuous positive airway pressure interrupted by regular, short, pressure releases. Unrestricted spontaneous breathing may occur throughout any part of the respiratory cycle.

Rationale:

APRV may be of particular use for patients with Acute respiratory Failure (ARF) or Acute Respiratory Distress Syndrome (ARDS).

Particular features which are thought to be of benefit include:

- Open lung approach to management of ARF/ARDS.
- Longer periods of time spent at the higher selected pressure allow areas of the lung with longer time dependent opening to be recruited.
- Intermittent pressure releases during APRV act to supplement spontaneous minute ventilation. These releases are short enough that they do not allow complete collapse of recruited alveolar sacs.
- Higher mean airway pressure (mPaw) than conventional ventilation. Higher levels of mPaw are directly correlated with lung volume and improvements in oxygenation.
- Avoidance of excessive peak airway pressures. High peak airway pressures are associated with barotrauma and worsening of the pulmonary pathological process. Excessive airway pressures are associated with increased mortality in ARDS.
- Spontaneous ventilation during APRV results in more dependent gas distribution than occurs with passive ventilation in conventional ventilatory modes. This may improve ventilation-perfusion matching with a consequent improvement in gas exchange. It may also result in preferential recruitment of dependent lung regions without the need for excessive airway pressures and may therefore avoid overdistension of non-dependent lung regions. Overdistension and high tidal volumes are also associated with increased mortality in ARDS.
- Because spontaneous ventilation is permitted throughout any part of the ventilator cycle, patients can often remain quite comfortable at relatively low levels of sedation. Reduced sedation requirements may have beneficial effects on cardiovascular function, and have been associated with reduced days spent on a ventilator, reduced likelihood of ventilator associated pneumonia (VAP) and fewer days spent in ITU.
- Concurrent spontaneous breathing during APRV has been shown to improve cardiac contractility as a result of augmentation of cardiac filling, and may also therefore reduce dead space ventilation.
- Avoidance of neuromuscular blockers is fundamental to APRV. Avoidance of these agents is associated with reduced incidence of critical illness neuropathy and myopathy.

Despite these potential advantages, it is important to recognize that current evidence demonstrates only that APRV is an effective mode of ventilation. No sufficiently large scale randomized controlled studies have taken place to evaluate its impact on outcome.

N.B. APRV is not recommended as a mode of ventilation for patients with COPD or asthma.

DETAILS OF GUIDELINE

The decision to use APRV and its initiation should only be made by a consultant intensivist or a senior trainee experienced in the use of APRV.

In addition to FiO_2 , adjustable parameters are:

P_{High}	High CPAP level at which the majority of the ventilator cycle is spent
P_{Low}	Low CPAP level to which the time-cycled breaths are released
T_{High}	Time spent at P_{High}
T_{Low}	Time spent at P_{Low}

Initial settings:

The patient should not be paralysed and should be sufficiently lightly sedated that they are capable of spontaneous ventilatory effort.

Automatic Tube Compensation (ATC) should be set to 100% and the correct airway type and size selected.

STEP 1:

P_{High} Set equal to plateau pressure on previous conventional ventilation mode or 30 cmH_2O (whichever is lower)

P_{Low} Set to 0 cmH_2O

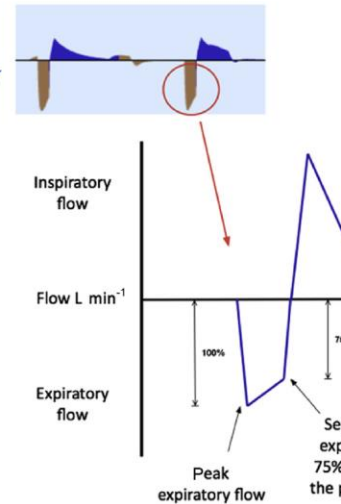
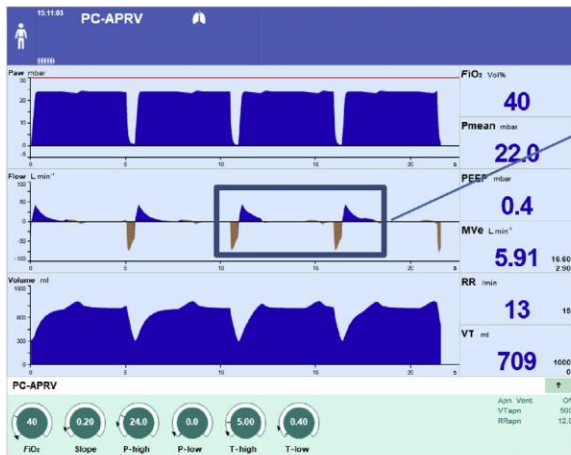
T_{High} 5 seconds

T_{Low} 0.5 second

FiO_2 1.0 or 0.2 greater than previous ventilator settings (for safety during initial transition to APRV from conventional ventilation)

STEP 2:

Immediately assess flow waveform and release volumes. T_{Low} should be adjusted until the expiratory flow rate decays to 75% of the peak expiratory flow rate.



P_{Low} should usually remain set at zero cm H₂O.

T_{High} should then be adjusted, depending upon the established T_{low} settings, so that releases occur approximately 12-15 times per minute in the initial phase.

Physiological goals:

Maintain PaO₂ ≥ 8.0 kPa

Maintain PaCO₂ such that pH ≥ 7.20

Subsequent evaluation:

1. Strategies to improve oxygenation

- Increase F_{iO_2}
- Increase P_{High} in 2-5 cm H₂O increments to a maximum of 30 cm H₂O (Aiming to exceed threshold opening pressure (TOP) of non-recruited lung regions). Re-evaluate T_{Low} settings after any change in pressure settings.
- Increase T_{High} in 0.5-2 second increments to a maximum of 10 seconds
- Reduce T_{Low} in increments of 0.05-0.1 second to optimize end-expiratory lung volume
- Optimise haemodynamic status to ensure optimum pulmonary perfusion.

2. Strategies to improve CO₂ clearance

- Assess for oversedation (inadequate spontaneous ventilation)
- Ensure T_{Low} is set to allow decay of expiratory flow rate to ~75% of peak flow rate.
- If P_{High} < 30, increase in increments of 2-5 cm H₂O to a maximum of 30 cm H₂O. Re-evaluate T_{Low} settings after any change in pressure settings.

- d. Decrease T_{High} in increments of 0.5-2 seconds to increase the number of pressure releases per minute.
3. Evaluation of sedation
 - a. Spontaneous ventilation is an essential prerequisite to the success of APRV. Sedation should therefore be titrated to achieve a spontaneous ventilation rate resultant in a $\text{pH} \geq 7.20$. This should usually be between 15 and 40 bpm.
 4. Evaluation of lung recruitment
 - a. As the lung is progressively recruited release volumes will increase. T_{Low} should be re-evaluated at least every 1-2 hours in the first six hours after initiation of APRV to ensure that expiratory flow decay curves remain “clipped” at about 75% of peak flow rates.
 - b. Throughout longer therapy lung compliance will alter with changes in lung pathology. Re-evaluation of settings should take place regularly.
 5. Weaning on APRV
 - a. Initially reduce P_{High} to maintain release volumes 6-8ml/Kg IBW
 - b. Progressively reduce FiO_2 to target ≤ 0.4 with $\text{SpO}_2 \geq 95\%$
 - c. Progressively wean by simultaneously reducing P_{High} (by increments of 2-5 cm H_2O) and increasing T_{High} (increments of 0.5-2 seconds) so that the minute volume generated by release volumes decreases and is gradually supplemented by increased spontaneous minute volume, until the patient has essentially been weaned to pure CPAP. Then convert to standard CPAP with low level pressure support and continue wean as usual.
 6. Failure of APRV
 - a. If unable to achieve adequate oxygenation or carbon dioxide clearance despite above manipulations of therapy consider alternative ventilation strategies, or advanced interventions such as Extracorporeal CO_2 Removal (ECCO₂R).
 - b. Consideration should simultaneously be given to other physiological manipulations such as diuresis or exclusion of other compliance limiting pathologies (e.g. drainage of pleural effusions, ascites etc)
 - c. In the event of excessive release volumes despite appropriately timed releases, consider alternative ventilation modes.

REFERENCES

1. Habashi NM. Other approaches to open-lung ventilation: airway pressure release ventilation. *Crit Care Med.* 2005 Mar;33(3 Suppl):S228-40.
2. Frawley PM, Habashi NM. Airway pressure release ventilation: theory and practice. *AACN Clin Issues.* 2001 May;12(2):234-46
3. Putensen C, Wrigge H. Clinical review: biphasic positive airway pressure and airway pressure release ventilation. *Crit Care.* 2004 Dec;8(6):492-7

Appendix 1

Predicted body weight and ventilator volume range charts

Predicted body weight and ventilator volume range chart FEMALE					
Non Acute Lung Injury		Height	PBW	Acute Lung Injury / ARDS	
6 ml/Kg	8 ml/Kg	(cm)	(Kg)	4 ml/Kg	6 ml/Kg
206	274	140	34	137	206
211	281	141	35	141	211
216	289	142	36	144	216
222	296	143	37	148	222
227	303	144	38	152	227
233	310	145	39	155	233
238	318	146	40	159	238
244	325	147	41	162	244
249	332	148	42	166	249
255	339	149	42	170	255
260	347	150	43	173	260
265	354	151	44	177	265
271	361	152	45	181	271
276	368	153	46	184	276
282	376	154	47	188	282
287	383	155	48	191	287
293	390	156	49	195	293
298	397	157	50	199	298
303	405	158	51	202	303
309	412	159	51	206	309
314	419	160	52	210	314
320	426	161	53	213	320
325	434	162	54	217	325
331	441	163	55	220	331
336	448	164	56	224	336
341	455	165	57	228	341
347	463	166	58	231	347
352	470	167	59	235	352
358	477	168	60	239	358
363	484	169	61	242	363
369	491	170	61	246	369
374	499	171	62	249	374
379	506	172	63	253	379
385	513	173	64	257	385
390	520	174	65	260	390
396	528	175	66	264	396
401	535	176	67	267	401
407	542	177	68	271	407
412	549	178	69	275	412
418	557	179	70	278	418
423	564	180	70	282	423
428	571	181	71	286	428
434	578	182	72	289	434
439	586	183	73	293	439
445	593	184	74	296	445
450	600	185	75	300	450
456	607	186	76	304	456
461	615	187	77	307	461
466	622	188	78	311	466
472	629	189	79	315	472
477	636	190	80	318	477

Please note that the key documents are not designed to be printed, but to be used on-line. This is to ensure that the correct and most up-to-date version is being used. If, in exceptional circumstances, you need to print a copy, please note that the information will only be valid for 24 hours and should be read in conjunction with the key document supporting information and/or Key Document intranet page, which will provide approval and review information.

Predicted body weight and ventilator volume range chart MALE					
Non Acute Lung Injury		Height	PBW	Acute Lung Injury / ARDS	
6 ml/Kg	8 ml/Kg	(cm)	(Kg)	4 ml/Kg	6 ml/Kg
233	310	140	39	155	233
238	317	141	40	159	238
243	325	142	41	162	243
249	332	143	41	166	249
254	339	144	42	170	254
260	346	145	43	173	260
265	354	146	44	177	265
271	361	147	45	180	271
276	368	148	46	184	276
282	375	149	47	188	282
287	383	150	48	191	287
292	390	151	49	195	292
298	397	152	50	199	298
303	404	153	51	202	303
309	412	154	51	206	309
314	419	155	52	209	314
320	426	156	53	213	320
325	433	157	54	217	325
330	441	158	55	220	330
336	448	159	56	224	336
341	455	160	57	228	341
347	462	161	58	231	347
352	470	162	59	235	352
358	477	163	60	238	358
363	484	164	61	242	363
368	491	165	61	246	368
374	499	166	62	249	374
379	506	167	63	253	379
385	513	168	64	257	385
390	520	169	65	260	390
396	527	170	66	264	396
401	535	171	67	267	401
406	542	172	68	271	406
412	549	173	69	275	412
417	556	174	70	278	417
423	564	175	70	282	423
428	571	176	71	285	428
434	578	177	72	289	434
439	585	178	73	293	439
445	593	179	74	296	445
450	600	180	75	300	450
455	607	181	76	304	455
461	614	182	77	307	461
466	622	183	78	311	466
472	629	184	79	314	472
477	636	185	80	318	477
483	643	186	80	322	483
488	651	187	81	325	488
493	658	188	82	329	493
499	665	189	83	333	499
504	672	190	84	336	504

Please note that the key documents are not designed to be printed, but to be used on-line. This is to ensure that the correct and most up-to-date version is being used. If, in exceptional circumstances, you need to print a copy, please note that the information will only be valid for 24 hours and should be read in conjunction with the key document supporting information and/or Key Document intranet page, which will provide approval and review information.

CONTRIBUTION LIST

Key individuals involved in developing the document

Name	Designation
Dr Mark Griffiths Professor Gavin Perkins Dr A Burtenshaw Dr G P Sellors	Consultant Physician in Adult Critical Care, Royal Brompton Professor in Critical Care Medicine, Warwick CTU Consultant, Intensive Care Medicine Consultant, Intensive Care Medicine

Circulated to the following individuals for comments

Name	Designation
Dr Steve Digby	Consultant, Intensive Care Medicine
Dr Steve Haynes	Consultant, Intensive Care Medicine
Dr Steve Graystone	Consultant, Intensive Care Medicine
Dr Edwin Mitchell	Consultant, Intensive Care Medicine
Dr Jeremy Thomas	Consultant, Intensive Care Medicine
Dr Gavin Nicol	Consultant, Intensive Care Medicine
Dr Tracey Leach	Consultant, Intensive Care Medicine
Dr Sean Chadwick	Consultant, Intensive Care Medicine
Dr Sian Bhardwaj	Consultant, Intensive Care Medicine
Dr Chris Mowatt	Consultant, Intensive Care Medicine
Dr Prashant Hegde	Consultant, Intensive Care Medicine
Dr Shiju Mathew	Consultant, Intensive Care Medicine
Dr Nick Fitton	Consultant, Intensive Care Medicine
Dr Nick Cowley	Consultant, Intensive Care Medicine (Locum)
Dr Mike McAlindon	Consultant, Intensive Care Medicine (Locum)

Circulated to the following CD's/Heads of dept for comments from their directorates / departments

Name	Directorate / Department
Dr G P Sellors	Consultant & Clinical Director, Critical Care
ICM Forum	Approved by ICM Forum 6 th May 2015